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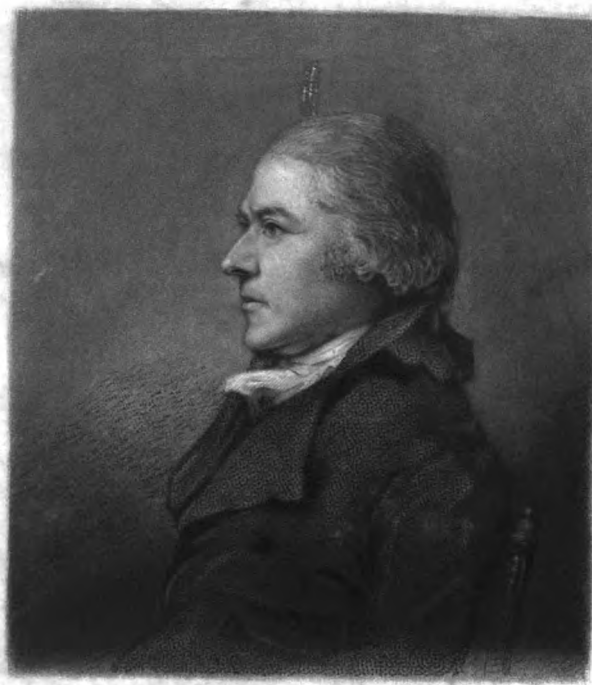


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CIVIL ENGINEER.

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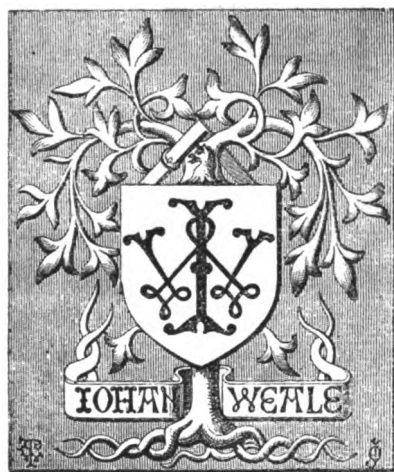
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E N G I N E E R I N G.

VOLUME I.

TWENTY-FIVE ENGRAVINGS ON COPPER AND WOOD.

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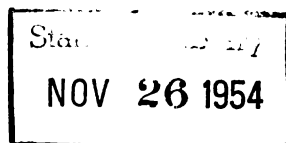
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TO
WILLIAM THOMAS DENISON, ESQ.,
CAPTAIN ROYAL ENGINEERS, F.R.S., ETC., ETC.
THIS VOLUME,
SPECIALLY DEVOTED TO CIVIL ENGINEERING,
A SCIENCE TO WHICH HE IS SO MUCH ATTACHED,
IS INSCRIBED,
BY HIS VERY HUMBLE SERVANT,
JOHN WEALE.

JAN. 1ST, 1844.

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MEMOIR OF JAMES BRINDLEY.

BY SAMUEL HUGHES, C.E.

THE memory of Brindley, associated as it is with the introduction of navigable canals into this country, must ever be regarded with interest and respect. The great canals which he himself executed are amongst the most important lines of communication which Great Britain yet possesses. By means of inland navigation, he connected the great port of Liverpool with the metropolis, and with Bristol and Hull, making numerous branches to every considerable manufacturing town, opening up in every direction the richest coal and iron fields in the kingdom, and affording an outlet for the timber, corn, and manufactured goods of extensive districts, whose commerce and prosperity date from the introduction of the canals which he executed.

ENG. I.

B

EARLY HISTORY.

All the information we have been able to collect respecting the early years of Brindley, is as imperfect and unsatisfactory as might be expected, when one proceeds to inquire into the history of a man who, springing from the humbler ranks of life, and being originally uneducated, never sought, in later years, any thing approaching to the fame of literary distinction. Brindley's contempt for authorship has become so proverbial, that many an idle student at the present day has professed to follow the example of the first, and it may be the greatest, of British engineers, when acknowledging that he cared not for the graces of composition—referring with perfect complacency to the recorded fact, that Brindley was scarcely ever known to use his pen, and that his literary productions were confined to the few letters which he was absolutely obliged to write.

Whether such an example were at any time worthy of being followed, is not now the question; nor is it necessary here to show how much men and things have altered since mankind first marvelled at the genius and excused the eccentricities of Brindley. It is sufficient for one moment to glance at the fact, that he to whom the penmanship of a simple letter was a drudgery not lightly or willingly to be encountered, was not likely to leave behind him many written materials to aid the researches of future biographers.

Brindley, however, is one of those whose history is identified with that of a great national era; with the developement of vast resources, with the rise of many great commercial cities, and with the general advance in civilization and grandeur of the country which claims the honour of his birthplace. The leading features only of the career of other men remain, and the history of the world has many phases which appear as the results worked out by master spirits in former ages. But where amidst the annals of all the great and glorious which the world has ever seen—where amidst the relics of all the orators, sages, statesmen, and warriors of old—these latter being especially dignified with the name of heroes—where will be found more imperishable traces than those in which Brindley wrote his own history upon the bosom of his own country? Deep indeed are the graven lines, and high in bold relief the swelling tracery which tracked over hill and dale, through mountain, grove, and forest, the fame and genius of Britain's earliest engineer! Long, too, shall that fame endure, long shall those lines continue to mark his benefits conferred on commerce, and to attest the countless comforts which, with magician's power, he bade to circle round his native country and his fellow men; multiplying over and over again,

the very means of existence, and sending enjoyments hitherto unknown into every hamlet and cottage in the land.

For the history of the man, therefore, we must look chiefly to these his great works. Their rise and progress correspond with the successive steps by which the genius of their engineer was developed, and the magnificent aqueducts and tunnels which he constructed on his canals, display, in a striking manner, the skill and talents of him who, in the infancy of engineering science, reared over deep valleys, and drove through lofty summits, works whose magnitude and difficulty have not been exceeded in the course of similar undertakings even up to the present day.

James Brindley, the subject of this memoir, was born in Derbyshire, in the year 1716. There is some disagreement, however, as to the exact place of his nativity. He was born, says the *Biographia Britannica*, at Tunsted, in the parish of Wormhill, and most of the short accounts of his life, having been copied from this work, agree in this statement. The notice, however, which appears in the preface to the first volume of the *Transactions of the Institution of Civil Engineers* styles the birth-place of Brindley an obscure village called Thornsett, near Chapel-en-le-Firth. As far as we have any means of judging at this distance of time, the statement in the *Biographia Britannica* appears entitled to the most credit, as the particulars of this kind were mostly contributed by Mr. Henshall, the brother-in-law of Brindley, very shortly after the death of the latter. It can scarcely be supposed that Henshall could be otherwise than correctly informed on such a point as this.

BRINDLEY'S APPRENTICESHIP, AND SUBSEQUENT EMPLOYMENT AS A MILLWRIGHT.

The father of Brindley possessed a small freehold property, which he appears to have dissipated and wasted away by indulging too much in shooting and other field sports, while he greatly neglected his domestic affairs, and bestowed no attention on the instruction of his children. Young Brindley, it appears, never received even the common rudiments of education, and his choice of mechanical employment, as the means of gaining his future livelihood, was entirely the result of his own natural and unaided inclinations. Up to his seventeenth year he appears to have been engaged in the ordinary agricultural labours to which the children of the poor are accustomed, and at this period of his life it was, that of his own accord he bound himself an apprentice to Mr. Bennett, a millwright, near Macclesfield, in Cheshire.

The way being thus opened for the exercise of young Brindley's mechanical bias, he seems to have made rapid progress in the business, becoming in a short time not

only a very superior workman, and competent to execute all the details of mill-work which were at that time known, but also a successful improver of several parts of the machinery then in use. He soon outstripped his master in the favour and esteem of the country people, and it is said that the millers, wherever he had been employed, always preferred his services in future to those of his master or of any other workman. There is one remarkable instance of Brindley's skill and energy, which, occurring at so early an age, may be worth recording. His master was on some occasion employed in the erection of a paper mill, which, being the first of the kind that had been attempted in that part of the country, excited considerable interest throughout the neighbourhood. Previous to commencing his operations, Mr. Bennett had made a visit to some mill which had been already put up, and had imagined he so far understood its working that he could construct his own to perform in the same manner. Brindley it appears had some misgivings as to the correctness of his master's proceedings, and had no great faith in the acquaintance he professed to have gained with the subject from the study of the model he had been inspecting. His doubts were accidentally confirmed by the assertions of another millwright who happened to be passing along the road, and who assured the country people, on seeing Mr. Bennett's work, that he was wasting the money of his employers, and would never be able with any success to carry into effect the object they had in view. After this warning it was that young Brindley, although at the time only an apprentice himself, and therefore having no great interest at stake in the success or failure of the work, determined to see for himself the mill which was to be taken as the model for the one they had in hand.

With this view, and without mentioning his intention to a single person, he set out one Saturday night, after the labour of the day was over, inspected the mill to be copied so minutely as to understand every part of its construction, and returned to his work on Monday morning, after travelling fifty miles on foot. He then informed his master of the particulars in which he had been wrong, and from that time the work went on with perfect ease and satisfaction until it was finished, with considerable improvements, to the great delight of the proprietors.

Mr. Bennett, who appears to have been of an advanced age at the time of Brindley's apprenticeship, grew unable to work before its expiration, and it is said that Brindley continued with him several years afterwards, carrying on the business with great credit, and supporting the old man and his family in a comfortable manner.

After the death of Mr. Bennett, Brindley continued the millwright business on his own account, gradually extended his fame throughout the neighbourhood, and

engaged by degrees in a much more extended practice than that in which his old master had instructed him.

During the next ten or twelve years of Brindley's life we have little or no information respecting him that can be relied on. In the year 1752, however, at which time he was thirty-six years of age, we hear of him erecting what is called "a very extraordinary water engine, at Clifton, in Lancashire, for the purpose of draining some coal mines, which before were worked at an enormous expense."* This engine consisted of a large water wheel which worked the pumps for draining the mines. The wheel was fixed thirty feet below the surface of the ground, and the water for turning it was brought from the river Irwell through a subterraneous tunnel, 600 yards in length, carried in one place through a rock. This appears to have been Brindley's first attempt at practice in that part of his profession from which he was afterwards destined to reap such imperishable renown.

At this time his mechanical abilities must have been pretty generally known, and he must have acquired some standing in public estimation, for we find him in three years afterwards, namely, in 1755, employed by N. Pattison, Esq., and some other gentlemen of London, to execute the larger wheels for a new silk mill at Congleton, in Cheshire. These employers of his, however, had not at first sufficient confidence in the skill of Brindley to commit the whole work to his care, since we are told that another engineer was entrusted with the manufacture of the smaller wheels, and with the general superintendence of the whole concern. This person, who had been employed before Brindley, had got into difficulties with the work, in consequence of which the proprietors became alarmed, and determined to call in the assistance of the latter, leaving still the chief management to their former engineer. This person accordingly assumed a superiority over Brindley, and attempted, as the phrase goes, to keep him down, by treating him as a common mechanic employed to execute a particular branch, and affecting a mystery about superior parts of the work which were above the comprehension of his subordinate. He therefore gave out to him the work in detached parts, not allowing him to see the model of the whole machinery, and not acquainting him with the result which was intended to be produced. This genius, however, soon found the impolicy of thus treating a man who was in every way superior to himself. Brindley for his part was mortified at being denied the opportunity of displaying that talent of his own which he knew to be equal to the task in hand, and complained to the proprietors of the inefficient position in which he stood. He assured them of his ability and readiness to take upon himself the completion of the mill to their perfect satisfaction, if they would let

* Kippis's *Biographia Britannica*, London, fol. 1780, Vol. II. p. 592.

him know the effect which they wished to have produced, and would allow him to carry on the work in his own way. The proprietors, aware of the ability and integrity of the man who made this representation, wisely determined to intrust him with the whole management; and the mill was accordingly completed by Mr. Brindley, in a manner which far exceeded their utmost expectations. In executing this work, as in all others with the particulars of which we are acquainted, Brindley introduced many valuable improvements, which made the machine greatly superior to what was originally contemplated.

A contrivance in this machine for winding the silk upon the bobbins in equal layers, instead of wreaths, is attributed to Brindley. He introduced contrivances also for stopping not only the whole machinery at any moment required, but also every part of it individually. He has also the credit of having made use at that early period of original machines for cutting the teeth of all the wheels and pinions in the different engines. It is said that, by Mr. Brindley's machinery for cutting these teeth, as much work could be done in one day as formerly occupied fourteen days when the labour was performed by hand.

The fame of Mr. Brindley continued steadily to increase, and about this time the potteries of Staffordshire received the benefit of his inventive skill, to which they were indebted for several valuable improvements in the mills which are used for grinding flints. This process was then, and for many years afterwards, performed by water power, and we are not able to say what was the precise nature of the improvements which Brindley introduced; they are said, however, to have materially reduced the cost of the process.

About the year 1756, Mr. Brindley's attention seems to have been directed to the subject of steam engines. In this year we find him erecting one of a peculiar construction at Newcastle-under-Line. The boiler, instead of being composed of iron plates, was built entirely of brick and stone, and the water was heated by fire flues of a new kind, which are said to have effected a great saving of fuel. A boiler of this kind made of non-conducting materials would undoubtedly economize more heat than an iron boiler which is not clothed on the outside. As for the flues, they were probably conducted through the interior of the boiler, as in the Cornish engines of the present day. Mr. Brindley's engine further differed from those before constructed in having steam cylinders of wood, strongly hooped and well fitted together, instead of iron, which has commonly been used both before and since. He also substituted wood instead of iron, for the chains attached to the piston rods at the end of the beam. These contrivances were introduced for the sake of economy, the disproportion between the cost of iron and wood being at that time much greater than it is now, and they are said to

have worked extremely well. Whatever may be thought of this the first application of Mr. Brindley's talents to the construction of steam machinery, it is certain that if he had continued to devote himself to this subject, great results might have been expected from abilities like his, so energetic, so persevering, and so well directed.

It may be fortunate or otherwise with respect to his future career, that his projects for the improvement of the steam engine were thwarted by the opposition and jealousy of other engineers, who threw every possible obstacle in his way, and decried every improvement of which they could not themselves claim the merit. The fact, however, that he was so thwarted and opposed by unworthy and jealous compeers, is as undeniable in his case as it is common in many others. So commonly, indeed, does such a fate encounter the efforts of genius, that it justly ceases to excite any kind of wonder.

BRINDLEY'S EMPLOYMENT BY THE DUKE OF BRIDGEWATER; WITH SOME ACCOUNT OF THE BRIDGEWATER CANALS.

The disappointment and chagrin which might have been supposed to spring from causes of this kind, were fortunately destined to make little impression upon the mind of Brindley, for his attention was now about to be called to a subject of still greater importance than any which had hitherto engaged it. We are not told on any good authority in what way Brindley first attracted the notice of the great Duke of Bridgewater*, that noble and munificent individual, by means of whose powerful and unflinching support he was able to carry into effect his earlier projects of inland navigation. This distinguished nobleman appears to have possessed a high and gifted intellect, a sound discerning judgment, and a bold spirit of indomitable perseverance, which, with pettier objects and less lofty aims in view, has been sometimes thought akin to obstinacy. Though born to inherit the most exalted rank which a subject can enjoy, the education of the duke is said to have been greatly neglected, in consequence of the tendency to consumption under which he laboured in his youth. In spite of this he grew up a strong and active man, possessed a spirit and courage which were

* The following anecdote, however, referring to the Duke of Bridgewater's first notice of Brindley, is related in the *Morning Post* of 11th August, 1776. "The first thing in which he distinguished himself was in advising the Duke how to stop a breach of a river that had been dammed up; he undertook it, and executed it by means of the liquid mud, which has ever since been used. It is to form the bank with an oblong board frame without top or bottom, for carrying a wall up in the centre of the bank, which is made by earth thrown into the frame full of water, violently agitated till it is a mass of mud, and then left to settle, continuing so till the wall is of the height intended, and this has been found far more effective than any ramming, and at the same time much cheaper."

never known to fail him, and many are the noble sacrifices which he made in order to carry out the success of the gigantic projects in which he had engaged.

It appears that the Duke of Bridgewater was an extremely young man—only 22 years of age—when he obtained his first Act of Parliament for making a navigable canal from Worsley. This Act refers to a former Act, which had been passed about 20 years before, namely, in the infancy of the then Duke of Bridgewater, for making navigable the stream called Worsley Brook, and goes on to recite that the persons empowered under that Act had neglected to carry it into execution; and that a cut or canal may be made from a certain place in the township of Salford, near Manchester, &c., to or near Worsley Mill, &c. It is therefore to be presumed that his Grace's attention may have been first called to the necessity of a communication between his coal mines at Worsley and the town of Manchester, by the project for making the brook navigable, which was entertained in the lifetime of his predecessor. It was reserved for himself, however, to carry into effect the far more complete project of making an entirely new canal on a perfect level throughout, instead of merely rendering the brook navigable.

The credit due to the Duke of Bridgewater as the originator of navigable canals in this country having been denied by some, who contend that the Sankey Brook Canal in Lancashire was constructed and designed before his, it may be proper to examine into the truth of this assertion. In the year 1755, an Act was obtained for making the Sankey Brook navigable from St. Helens to the river Mersey, but the proprietors of this navigation afterwards determined to abandon the stream, and to make an entirely new canal, using the water of the stream merely to feed the canal. Accordingly, the canal was dug as close along the side of the stream as practicable, and opened for navigation in the year 1760. In the mean time, the Duke of Bridgewater applied to Parliament (in 1758) for power to construct a canal, not in the bed of any stream, not near to or parallel with the course of any stream, but entirely across the dry land, and quite irrespective of the position of streams, except in so far as they might be made to afford supplies of water to his canal. Upon a consideration of these facts, I confess myself unable to see any ground whatever for putting the merit of any other person in this respect in competition with that of his Grace, who undoubtedly deserves the whole credit of planning, at the time of attaining his majority, a work which reflects immortal honour on his memory, and confers a rank upon him greater—immeasurably greater—than all that which is due to his titles or his station. Undoubtedly he had seen and studied the great canal works of Holland, Italy, and other countries, and he deserves undivided credit for having so perseveringly determined to see them imitated in his own country and through his own means.

It is impossible to look into the history of inland navigation in this country without being struck by its extremely slow progress. Long after China, Holland, France, Italy, and Sweden had displayed the advantages of communication by still-water canals, we find the utmost ambition of the most enterprising individuals in this country confined to proposals for making navigable the existing streams of rivers, by penning up their waters, and occasionally introducing a rude species of lock, which they termed a *sasse*. Thus we find in the year 1656 an individual named Francis Mathew, addressing the Protector Cromwell and his Parliament on the immense advantage of a water communication between London and Bristol. But how does he propose to effect this object, for which, after the lapse of a century and a quarter, three great canals were undertaken, under the names of the Thames and Severn, the Kennet and Avon, and the Wilts and Berks; these in their turn being thrown into utter insignificance by the construction of a work no less important than the Great Western Railway, connecting and bringing within six hours of each other the two same ports to which Mathew, nearly 200 years ago, sought to draw the attention of the government? Mathew, in his day, was probably considered a bold and daring speculator; and what was the extent of the plan by which he proposed to effect his object? It was this: to make the rivers Isis and Avon navigable to their sources by means of *sasses*, and to connect their heads by a short canal of three miles across the intervening ridge of country. It is amusing enough to follow the arguments of this primitive amateur—for he ventures not to call himself an engineer—in his endeavour to convince the world that his project, novel and gigantic as he admits it to be, is not beyond the capacity of the *state* to execute. As for private enterprise, whether by individuals or by a corporation, he considers it quite out of the question for such a work; but he ventures to think that the state might undertake it with a reasonable prospect of success.

The condition of engineering science in the time of Mathew (1656), may be inferred from the following extract from his book^a relating to the general subject of inland navigation. He recommends “to rise as high in opening the said rivers as they shall be found feasible, there to make a wharf, magazine, or warehouse for all such commodities as are useful to those parts of the country, both for trade in merchandizing, and service in time of war, with far greater expedition.

“If any other river practicable for boats lye near the head or side of the said river, and that the ground favour the opening of a still river to be drawn between

^a Of the Opening of Rivers for Navigation: the benefit exemplified by the two Avons of Salisbury and Bristol, with a Mediterranean Passage by Water for Billanders of thirty Ton, between Bristol and London, with the Results. London, 1656.

them, then to joyn them with sasses, *alias* locks, or otherwise. But should the ground be repugnant, then a fair stone cawsey, not exceeding one little daie's journey for horse, or carts, to be raised between the said rivers. Where the navigation ends, a wharf or magazine to be made as aforesaid, if these reach from sea to sea, not otherwise. For the example of cawseys, let the head of Foy river, and that of Padstow, in Cornwall, be examined, for a cawsey to be made between them.

“By the like industry, many mediterranean passages by water, with the help of such cawseys, would be formed from one sea to the other, *and not to have the old channel of any river to be forsaken for a shorter passage.* For, as hath been said, rivers are never out of their way; and upon these navigable passages, our chief manufactures should be set up for the commoditie of transportation.”

Only four years after this display of science, we find Francois Audreossy, an Italian engineer, proposing in France the great canal of Languedoc, to connect the Atlantic Ocean with the Mediterranean Sea, and in 1667 was commenced this magnificent work, which is no less than 148 English miles in length, with a breadth of 64 feet at the surface of the water, 34 feet at the bottom, and a depth of $6\frac{1}{2}$ feet.

The canal of Languedoc, besides its immense reservoirs for collecting water at the summit, has more than 100 locks, some being of a circular form and of immense size, 55 aqueducts, a tunnel, and 92 road bridges. It is navigable for vessels of 100 tons' burden, their size being commonly 85 feet long, 17 to 19 feet broad, and draught of water 5 feet 4 inches.

But long before the canal of Languedoc was proposed, France already possessed canals, the principal of which is that of Briare, between the Loire and the Seine, executed in the reign of Louis XIII. Holland may be almost said to have led the way in modern Europe with respect to still-water navigation. When, as we have seen, the utmost ideas in this country, with respect to inland navigation, extended no further than to render navigable existing rivers, Holland had for centuries been intersected by numerous canals, remarkable even at this day for their size and magnificence. To say nothing of the canals executed in Holland in the time of the Romans, we find, in the fifth century, Meroveus, King of the Franks, cutting a navigable channel from the Meuse to the Waal, at Dordrecht; and in the tenth century, the Emperor Otho constructed a canal from Ghent to the sea. Not to multiply examples, enough has already been said to show that Holland, from a very early period, possessed the advantages of canal navigation, and the same may also be said, although not to the same extent, of Sweden and Italy. All these countries, in fact, were far before our own, at the period when the Duke of Bridgewater came to his estate; and

he has decidedly the credit of being the first to start in that race of internal improvement, in which Great Britain has now outstripped all other nations.

It is time, however, to return from this long digression to the more immediate subject of the present memoir, whose first canal was that from the Duke of Bridgewater's coal mines at Worsley to the town of Manchester. The length of this canal from Worsley Mill to Manchester is $10\frac{1}{4}$ miles, but in addition to this, there is now an extent of 30 miles of underground canal, connecting the different workings of the mine. The enterprising nobleman, who projected this navigation, deserves the gratitude of posterity for the energy he displayed in the prosecution of this and similar undertakings, and for the support which he afforded to his engineer under the pressure of great financial difficulties.

The rich mineral property of the Duke of Bridgewater is situated in the south Lancashire coal field, and at the foot of the mountain, where the open navigation commences, a large basin was excavated of sufficient capacity to contain a great many boats, and to serve as a head for the canal. The principal work on this canal is the Barton aqueduct over the river Irwell. It consists of three semicircular arches, the centre one being of 63 feet span. The canal is carried over at a height of 39 feet above the river; this head-room being sufficient for the largest barges which navigate the Irwell to pass under without lowering their masts.

The construction of this aqueduct excited great admiration at the time; it was, indeed, an effort quite unprecedented in this country, and the engineer deserves the more credit, when we consider that his aversion to any thing like books prevented him from deriving, by study, any information respecting those celebrated works of the Romans, in France, Italy, and Spain, which afforded the only examples of aqueducts at that time known to the world.

The writers of the day speak in terms of great enthusiasm of the strange and novel sight which the canal displayed at the place where it crossed the Irwell. Spectators were particularly struck with the advantages of still-water navigation, when on looking down from the canal bank, near the aqueduct, 10 or 12 men might be seen slowly hauling a single barge against the stream of the Irwell, while, 40 feet above it, a horse, or a mule, or sometimes two men, were drawing several barges linked together, on the smooth water of the canal. The aqueduct is entirely built of stone, all those in the faces being dressed on the front, beds, and joints, and cramped with iron. The canal, in passing over the arches, is confined within a puddled channel to prevent leakage, and although the work is not equal in point of merit to the canal aqueducts of modern days, in which cast iron has been used for the channel of the

canal, it must undoubtedly be considered a bold and ingenious enterprise for the time at which it was undertaken.

It was of course to be expected, that Brindley, in proposing a work of this kind, would meet with the disapprobation of those whom nature has condemned to the drudgery of one beaten path, and whose disposition would never lead them to improve upon the common instincts of their species. Accordingly, we find that a great outcry was raised against the madness and folly of attempting to carry one body of water over another in the way which he proposed. By his own desire, therefore, another engineer was consulted upon the practicability of such a work. We have not the name of this wiseacre to refer to, nor is it of much consequence to know it; he is only the type of a class who, in all ages, have endeavoured to thwart and combat the genius of men superior to themselves. In the present case what this man said is not of much consequence, because he failed in convincing the world of the madness of Brindley's project. For his own part, he was filled with horror at the recklessness of such a proposal; and in the conclusion of his report intended, no doubt, to carry a thunderbolt of alarm into the minds of all who could be so rash as to rely upon the representations of Brindley. After expressing in the most unqualified manner, his opinion of the impracticability of the work, "I have often heard," he says, "of castles in the air, but never before saw where any of them were to be erected." And yet this castle in the air was erected, and there it stands to this day; and could the dolt who thus expressed himself be now recalled to life, he might witness annually thousands of boats passing over some hundreds of such structures which have since been erected. Let the miserable ridicule with which subsequent events overwhelmed the conceited opinion of Brindley's contemporary, prove a warning to those who, in the fulness of their own vanity and ignorance, would rashly condemn the projects of men whom nature has destined to be ever in advance of the times in which they live.

It need scarcely be told now that the Duke of Bridgewater had sufficient firmness and penetration to support Brindley in his project against the opinion of this individual, and within one year from the time when the aqueduct he had designed was likened to a castle in the air, the water of the canal peacefully assumed its assigned level above the tideway of the Irwell, and the laden barge floated calmly over its tranquil surface.

The principal earth-works, which in those days presented difficulties in the execution of this canal, are the embankments across the low grounds on each side of the Irwell. The embankment across Stretford meadows is described by a writer of the

day as an amazing bank of earth, 900 yards long, 17 feet high, and 112 feet in breadth at bottom. The top breadth of the canal is 24 feet, and the breadth of bank on each side is 10 feet, so that according to the bottom breadth stated above, for a depth of 17 feet, it appears the slopes were 2 to 1, which was probably the case. What would have been the astonishment of Brindley's contemporaries could they have witnessed the railway and canal embankments of the present day, some of which are 4 times the height of the one which they considered so amazing, and contain 50 times the quantity of earth. However, Brindley's embankment was undoubtedly a great work for that time, and it must be remembered, that to confine and carry a body of water within a watertight trunk composed of earth—at all times a more difficult task than the construction of a railway embankment—requires nearly as much skill when the height of the bank is only 17 feet as when the height is quadruple of this.

The canal between Barton and Manchester, being mostly on sidelong ground, is cut down on the upper side and embanked up on the other by the excavated earth. At the crossing of a stream called Cornbrook, which is too high to pass under the canal at its natural level, a weir is built, over which the stream falls into a large basin, from which it flows into a smaller one, which latter is open at the bottom. The water is then conveyed by a culvert under the canal, rising on the other side in a well and flowing off at the level of its natural bed. Several public roads between Barton and Manchester pass under the canal, having been lowered several feet to afford them sufficient head room.

When it was determined to make the extension of the canal from Longford Bridge, which will presently be described, the waters of the Medlock were diverted into the canal at Manchester, and a large weir erected to regulate the height and carry off the surplus water.

The completion of this canal of course gave great facilities for conveying coals and other minerals to Manchester, and the erection of machinery for loading and unloading, together with many ingenious contrivances at both extremities of the line, displayed here, as in every former work of his, the great range and extreme fertility of Brindley's inventive genius. The subterranean canals or tunnels at Worsley are in some places arched with brick, and in other places the rock is sufficiently solid to stand without arching. Numerous air-shafts are sunk from the surface down to the roof of the excavations. At the entrance of the tunnel under the hill the arch is 6 feet wide and 5 feet in height above the surface of the water. The width is greater, however, in the interior, and there are many places at which the boats can pass each other. The coals are brought to the canal from the different workings in small low

waggons, which hold about a ton each, and are shot at once from these into the boats.

A steam engine was erected by Brindley for draining the coal mines at Worsley, but we have no particulars of this engine except that it was said to have cost only £150, the narrator^a remarking at the same time that no one before knew how to make such a one for less than £500. He also constructed, near the entrance of the underground canal, an overshot mill, which works three pairs of stones for grinding corn, besides a dressing or boulding mill, and a machine for sifting sand and mixing mortar. In this machine the mortar was compounded by means of two stones revolving obliquely upon a large horizontal stone, which was set in motion by a cog wheel fixed probably on the main shaft of the water-wheel.

Brindley also introduced improvements into the cranes for hoisting stones out of the quarries at Worsley, and erected at the mouth of the cavern a machine called a water-bellows, for forcing fresh air into the interior of the mine^b.

The canal was at first intended to terminate in Manchester at the foot of Castle Hill, up which the coals were conveyed in wheelbarrows and carts from the boats. To render the distribution of the coals, however, more economical, Mr. Brindley extended the canal for some distance into the hill, and opened a shaft at its extremity from the surface of the ground down to the canal. The barges then being introduced to the foot of this shaft, the coal is hoisted up by a crane, which is worked by a box water-wheel, of 30 feet diameter and 4 feet 4 inches wide. The cost of this canal is said to have been one thousand guineas per mile; a remarkably small sum, even considering the superior value of money in those days. The Acts of Parliament which authorized the formation of the canal, were obtained in the years 1758 and 1759. The boats employed in the underground canals are 50 feet long, 4½ feet broad, and 2 feet 3 inches deep.

During the execution of this, the first great project of the Duke of Bridgewater, it occurred to him that an extension from Longford Bridge, a point on the canal 6 miles distant from Worsley, to some part of the estuary of the Mersey, would prove to be

^a The writer of a letter in the Saint James's Chronicle of 30th Sept. 1763.

^b It is probable these water-bellows have been long since taken down. They are thus described by the writer of the letter referred to in the last note:—"At the mouth of the cavern is erected a water-bellows, being the body of a tree, forming a hollow cylinder, standing upright; upon this a wooden basin is fixed, in the form of a funnel, which receives a current of water from the higher ground. This water falls into the cylinder, and issues out at the bottom of it, but at the same time carries a quantity of air with it, which is received into tin pipes and forced to the innermost recesses of the coal pits, where it issues out, as if from a pair of bellows, and rarifies the body of thick air, which would otherwise prevent the workmen from subsisting on the spot when the coals are dug."

of immense public and individual benefit, by completing an efficient water communication between Liverpool and Manchester. Surveys were accordingly made, from which it was found that this extension could be made on a perfect dead level, till within three quarters of a mile of the river Mersey, and that the canal would then communicate with the river by a suite of locks having an aggregate fall of 79 feet. The length of this extension is something more than 24 miles, and its execution was no sooner determined upon, than the Duke of Bridgewater applied for a third Act of Parliament. This Act empowers his Grace to make a navigable cut or canal from Longford Bridge, in the township of Stretford, in the county of Lancaster, to the river Mersey, at a place called the Hempstones, in the township of Halton, in the county of Chester. It being afterwards found, however, that a greater depth of water, and consequently a more regular access to the canal, might be obtained by carrying it to a lower point on the Mersey, it was determined to abandon the Hempstones, and to make the entrance at Runcorn, where the depth is sufficient to permit the ingress and egress of boats even at the lowest tides.

The course of this canal lies entirely in the lower part of the new red sandstone; and the principal earth-works consist of clays, marls, bog earth, and occasionally of the sandstones of this formation. Considerable difficulties were occasioned by the scarcity of lime in this district, there being no calcareous rock in any of the cuttings. The distance from the Bedford limestone, near Leigh, was so great that the carriage, by the common roads of those days, caused the masonry of the bridges, locks, and culverts to be very expensive. It is said, however, that during the progress of the works a marl was met with which contained a sufficient proportion of calcareous ingredients to make lime when pressed into moulds and burnt like bricks. This account is given by Phillips, in his "General History of Inland Navigation," but we know not how far it may be depended on. If correct, the lime thus made would appear to be the first cement of which we have any knowledge in this country; since the calcareous marl here spoken of would probably produce, when burnt, a lime of strong hydraulic properties.

The course of the canal from Longford Bridge to Runcorn Gap lies in a south-westerly direction for some distance, and about two miles from Longford Bridge it crosses the river Mersey at a place about five miles east of the junction of that river with the Irwell. The canal continuing a south-westerly direction, proceeds nearly to Altringham, where it bends still more to the west, crossing the river Bollin three miles beyond Altringham. After crossing the Bollin the canal bends round to the south, and again to the north, describing nearly a semicircle, and then continues in the valley of the Mersey, and nearly parallel with the river, as far as the crossing of the

main road from Chester to Warrington. Beyond this road the canal bends round to the south in order to preserve the high level, passing for several miles in a southerly direction nearly as far as Preston, in Cheshire, when it turns again towards the north, pursuing a north-easterly direction for a mile and a half, and then changing to a westerly direction, in which it continues to Runcorn, where it falls into the estuary of the Mersey.

Let us now glance for a moment at the effect of these canals, and the benefits they conferred upon the districts which surrounded them. In the first place, they opened a good water communication between Manchester, Salford, the populous neighbourhood around it, and the richest part of the South Lancashire coal field; and secondly, they completed an efficient communication between Manchester and Liverpool, superseding the imperfect navigation of the rivers Mersey and Irwell above Warrington. The entrance of the canal at Runcorn was so designed that the barges of his Grace could enter and go out at the lowest neap tides, so that between the interior and the whole line of coast on both sides of the Mersey, a communication was thus effected, with no interruption, save that of a delay, at the worst times, of the interval from low water to nearly high water of the same tide. The noble undertaker of these great works was not only limited to a maximum rate of tonnage and freight for goods carried on his canals, but even consented that no coals brought from his mines into Manchester or Salford should be sold at more than four pence per hundred weight^a, which is little more than half what the public had formerly paid for this prime article of necessity. The Act of Parliament, therefore, which authorizes the formation of the canal from Worsley, makes this enactment in favour of the public interests, stamping at once in this way the great general boon conferred by the Duke of Bridgewater's enterprise, and affording favourable evidence of the public spirit which actuated his Grace, and of the clear-sighted penetration which led him to conclude that, even under a restriction so unusual and severe, his projects would yet realize the sanguine expectations he was led to entertain of their pecuniary success.

The canal between Manchester and Runcorn conferred general advantages no less important than the other. The price of land carriage between Liverpool and Manchester, before the commencement of the canal, was no less than 40s. per ton, and the price charged for goods conveyed by the tedious and uncertain navigation of the rivers Mersey and Irwell was 12s. per ton from Manchester to Liverpool, and 10s. between Manchester and Warrington; whereas his Grace consented to be limited by

^a The hundred weight here spoken of contains seven score, or 140 pounds, making the price of the coals 5s. 4d. per ton.

his Act of Parliament to a charge of 6s. per ton for the whole distance between Liverpool and Manchester.

It is probable that the Duke of Bridgewater's enterprise was urged on by the greedy and extortionate spirit displayed by the proprietors of the Mersey and Irwell rivers' navigation, who of course had no competition before the Bridgewater canals were undertaken. On coming to his majority, the Duke found himself charged for tonnage alone with an amount of 3s. 4d. for every ton of coal and other articles which had to pass from Barton on the Irwell up to Manchester, a distance of less than seven miles, this being the whole tonnage which the proprietors are entitled to charge upon goods which pass all the way up from Liverpool. Now there being no way in which the produce of his Grace's mines could be taken to Manchester, except by land carriage down to Barton, and thence by the river, it will readily be conceived that such an extravagant impost was calculated to exclude his coal from the market, except at a loss to himself or at an immense charge to the public. The alarm with which these greedy proprietors viewed the subsequent proceedings of his Grace, may be gathered from an offer which they made of allowing him the free use of their navigation for 6d. per ton, if he would consent to join his canal to their river. Fortunately his Grace rejected this overture, continued to pay their demand of 3s. 4d. per ton for considerable quantities of timber and other articles, which for some time he was obliged to carry on the river, and at length completely triumphed over and fitly rewarded them by sailing barges of his own, both over and alongside their river, to the general delight and satisfaction of all but those who were interested in the old river navigation.

The advantages of the Bridgewater Canals will be better understood by considering a little further the state of the existing navigations at the time they were proposed. The proprietors of the Mersey and Irwell navigation had then been incorporated about forty years, and such was the state of their navigation, that it was only at spring tides that boats could pass between Liverpool and their lowest lock. There were no wharfs or quays of any sort for landing and warehousing goods on any part of the river between Warrington and Manchester, a distance of 26 miles, and although their tonnage dues were granted on condition that they should render the navigation practicable at all tides, they had done nothing whatever to improve it below Warrington Bridge. It was between this point and the Hempstones, where the Bridgewater Canal was at first proposed to terminate, that the depth of water was so small as to prevent boats from navigating, except at spring tides. No coals had ever been carried, upon the old navigation, higher than Warrington Bridge, and no goods had ever been carried higher than this place for the supply of any part of the adja-

cent country between Warrington and Manchester; a fact which shows in a striking point of view the comparative inutility of imperfect navigation, and the mischief of high rates of tonnage. The freight and tonnage charged by the river for deal planks and other timber amounted to at least 20 per cent. of their value at Liverpool.

It has already been stated that the two first Acts which authorized the canal from Worsley to Manchester, were obtained in 1758 and 1759. The Act for the extension to Runcorn Gap was obtained during the progress of that canal, in the year 1762. The remaining part of the Bridgewater navigation, which it may be proper to notice in this place, is the Stockport Branch, which joins the canal to Runcorn Gap at Sale Moor, nearly three miles south of Longford Bridge; and which was also planned and executed under the superintendence of Mr. Brindley. This branch is $7\frac{1}{2}$ miles in length, and rises in all 60 feet from Sale Moor to Stockport. By means of this canal, the Act for which was obtained in the 6th of Geo. III., the advantage of water communication with Liverpool was extended to Stockport, and similar benefits realized to the surrounding country as by the former canals.

The following statement of the lengths and levels of the Bridgewater Canals is from a map* published by Mr. Brindley himself, and may therefore, it is presumed, be strictly relied on, although the distances differ from those given in most other accounts which have been published:

HIS GRACE THE DUKE OF BRIDGEWATER'S CANALS.

(By Acts 32, 33, Geo. II.—2 and 6 Geo. III.)

	miles. furl. chains.			
From Worsley to Longford Bridge	6	0	0	Level.
Longford Bridge to Manchester	4	2	0	Level.
Longford Bridge to Preston Brook	19	0	0	Level.
Preston Brook to the upper part of Runcorn	4	4	0	Level.
The upper part of Runcorn to the river Mersey	0	5	7	79 ft. fall.
Sale Moor to Stockport	7	4	0	60 ft. rise,
	41	7	7	139 feet.

I cannot conclude this account of the Bridgewater Canals without adverting to the great exertions and personal sacrifices made by his Grace for the sake of carrying out

* "A Plan of the Navigable Canals now making in the Inland Parts of this Kingdom for opening a Communication to the Ports of London, Bristol, Liverpool, and Hull, with the adjacent Towns and Rivers, by James Brindley, Engineer." This map is published by and for James Brindley, and dedicated to the Duke of Bridgewater. Date, 27th of April, 1769.

his great projects. For many years he devoted the whole of his large fortune to the prosecution of the works, and strictly confined himself to an income of £400 per year. Notwithstanding the great personal sacrifice thus made by his Grace, the progress of the works was at times severely embarrassed for want of funds. It was said to have been a principal employment of Mr. Gilbert, his Grace's agent, to ride up and down the country endeavouring to raise money on promissory notes, signed by the Duke; and at one time the financial difficulties had become so great that it was found impossible to procure cash on the Royal Exchange on his bond for £500.

It is within the knowledge of most persons in these days, that not only were all these difficulties successfully overcome, but that the concern in whose favour they had been endured, became speedily one of the most profitable in the kingdom. One cannot reflect, without a feeling of great admiration and respect, upon the generous and self-denying struggles made by the youthful nobleman who had the honour of projecting these great undertakings; and it affords infinite satisfaction to know that he was in time rewarded alike by the benedictions of the whole country which he had so eminently served, and by the successful issue, in every sense of the word, of the projects for which he had risked and endured so much. At the time of his Grace's death, in 1803, it was understood that the income arising from his canal property alone was between £50,000 and £80,000 per annum; and the property has increased in value since that time.

It may be interesting to glance for a moment at the present condition of the South Lancashire coal field, with respect to means of communication, since this will strongly exhibit the value and importance of such facilities to commerce, as were first afforded in this district by the Bridgewater Canals. First, then, the great trade carried on between Liverpool and Manchester, and the intermediate country, has, since that time, called into existence the Mersey and Irwell navigation, which is a cut extending on the south side of the Mersey from Runcorn Gap to below Warrington. Secondly, the canal across Cuerdley Marsh to the road from Liverpool to Warrington, after crossing which, it proceeds to St. Helen's, and affords an outlet for the produce of numerous coal mines in the neighbourhood of that place. Thirdly, the canal from Worsley to Leigh, extending the convenience of the Bridgewater navigation to the mines in the neighbourhood of Leigh, Pennington, and Ashton. Fourthly, the canal from Manchester to Bolton-le-Moors, with a branch to Bury on the Irwell, which opens up numerous mines between Worsley and Bolton, and a few between Bolton and Bury. Fifthly, the Rochdale Canal, which brings the coal north of Manchester into competition with that which lies in the western part of the field. In addition to these, which are communications called for by the immediate wants of the district itself, there is

the great Leeds and Liverpool Canal, a work which will be hereafter mentioned, which in its tortuous course winds through many miles of the north-western part of the coal field, and touches upon the rich collieries of Orrel, Wigan, Haigh, Chorley, Blackburn, Altham, Burnley, Great and Little Marsden, &c. Nor must we omit to notice the railways which, in modern times, have been executed in this district. First in importance stands the Liverpool and Manchester Railway, which runs through about twelve miles of the coal field from Roby to Newton, passing near to numerous collieries about Prescott, Sutton, Burton Wood, and Newton. The North Union Railway passes entirely across the coal field from Preston to Newton, where it joins the Liverpool and Manchester, passing close to the collieries of Wigan and some other places. There are besides, the Bolton and Leigh Railway, and the Bolton and Manchester, the former of which joins the Liverpool and Manchester. Two miles south of Leigh, the collieries of St. Helen's have a communication by railway with the Mersey at Runcorn Gap; and the Manchester and Leeds Railway passes through the coal field nearly in the line of the Rochdale Canal, passing close to Rochdale itself, and continuing its course through the busy manufacturing district of the vale of Todmorden. Many of these flourishing and important undertakings being in direct competition with the Bridgewater Canals, it will naturally be asked whether the trade of the latter has been injured by such a vast increase of accommodation as the other projects have created.

The answer is extremely gratifying, since it appears that some time after the completion of the Liverpool and Manchester Railway, when its effect upon the Bridgewater Canals was the subject of anxious investigation, the receipts of the canal, instead of being diminished, had been considerably increased; a result this that clearly proves the constantly extending commerce and prosperity of the country, which by successive degrees has called into existence and become able to support so many gigantic undertakings.

CANAL FROM THE TRENT TO THE MERSEY.

The Bridgewater Canals were completed about the year 1767, but some time before this the general attention of the country was beginning to be interested in the subject of inland navigation. Whilst the main line of canal to Runcorn Gap was in course of execution, the Bill for the Stockport Branch was before Parliament, and previous to the entire completion of the Bridgewater Canals, we find Brindley actively engaged in surveying, for the purpose of an immediate application to Parliament, a line of no less magnitude than the one from the Mersey to the Trent. This project, by far the most important which had hitherto been proposed with respect to

the inland navigation of this country, had been originally entertained as far back as the year 1755. In that year, at the expense of the Corporation of Liverpool, a survey of this line of canal was made by Messrs. Taylor, of Manchester, and Mr. Eyes*, of Liverpool. The name of Mr. Hardman, who was then member for the borough of Liverpool, and a most active and able advocate of commercial enterprise, has been also identified with the promotion of this work, in which he took a sincere and lasting interest.

In the year 1758, directly after the commencement of the canal from Worsley to Manchester, Brindley had been employed by Earl Gower and Lord Anson to survey and examine a line of country which would be suitable for a canal to connect the Mersey with the navigable part of the Trent, and the result of this survey was a decided opinion by Brindley that no part of the country was better adapted for an union of the German Ocean with the Irish Sea, and that no measure afforded a higher prospect of success, than one which proposed, like this, to bring the great ports of Liverpool and Hull into immediate communication by means of an uninterrupted line of inland navigation.

It is probable, however, that the magnitude of the undertaking appeared, in the opinion of most persons, to require that its prosecution should be delayed until after some experience had been acquired as to the actual working of canals in England.

The project of the Trent and Mersey Canal was revived in 1760, when a public meeting was held at Sandon in Staffordshire. At this meeting, which was attended by great numbers of the land owners and manufacturers of Staffordshire and the neighbouring counties, Lord Gower presided, and considerable difference of opinion prevailing as to the course which should be taken, and as to the place where the canal should join the Trent, it was ordered that Mr. Brindley, in conjunction with Mr. Smeaton, should make a survey of the whole line from one tideway to the other. For this purpose the sum of one thousand pounds was subscribed, and at another meeting, which was held in the same year, the two engineers attended with part of their surveys. At this second meeting, which was held at Wolseley Bridge, in Staffordshire, the plan of the canal from Wilden, on the Trent, to the summit at Harecastle, was ordered to be engraved, and copies of this plan were circulated amongst the land owners and others who were interested in the project.

Notwithstanding the notoriety thus given to the measure, and the general interest which appears to have been aroused in its favour, it was now quietly suffered, from what cause it is difficult to say, to slumber for a period of five years; as we can find no

* Mr. John Eyes, of Liverpool, was the original engineer of the Sankey Canal.

account of any public steps being again taken towards its prosecution till the year 1765. By this time the great success of the Duke of Bridgewater's undertakings had removed all doubt as to the practicability and advantages of canals, and the public mind had become fully impressed with the necessity of devising some means to enable the potteries, and the mineral districts which surround them, to continue the export trade which they had already begun to carry on. Accordingly, we find that the proprietors of the Staffordshire potteries came forward on this last occasion, as indeed they had done before, in the character of strong advocates for the measure. It is difficult to conceive, judging from the rapid progress of speculations at the present day, when brought forward under favourable circumstances, how, with a union so powerful as that which appears to have existed in this case between the landed proprietors and the manufacturing and monied interests, the prosecution of this measure should from time to time have been retarded during such long intervals. The apathy of the five preceding years was, however, amply atoned for by the vigour of the measures which were taken in 1765. In this year four general public meetings were held, and in the interval between the meetings every exertion was made to reconcile conflicting interests and to draw all parties into concurrence with the scheme. Subscription lists were kept open during this year at the principal towns along the line, and the amount subscribed continued steadily to increase, till at the general meeting held at Wolseley Bridge, in December, 1765, it was declared that the surveys having been satisfactorily completed, and many different lines having been considered, the meeting unanimously agreed to petition Parliament for a canal from the river Mersey to the river Trent at Wilden Ferry, with branches to the principal towns along the line.

This canal was called by some, at the time, the canal from the Trent to the Mersey, but Brindley, with a characteristic spirit of foresight, which indulged the idea that numerous branches would spring from this canal, as from a parent stem, always insisted on calling it the Grand Trunk Navigation or Canal, by which name, as somewhat shorter than the other, we shall probably speak of it in future. The friends of this undertaking, at the time they were combating the opposition which was arrayed against it, made use of the following general arguments in its favour. They said that the course of the line and its termination at Wilden had been determined after repeated surveys and investigations, continued during a space of ten years. That its execution would be a great public and permanent benefit to the agriculture and commerce of the kingdom. That it would reduce the price of carriage to one fourth its former amount, and thereby enable our manufacturers to meet their commercial competitors in foreign markets upon much more favourable terms than hitherto.

That by removing heavy traffic from the roads, it would greatly preserve them and reduce the expense of keeping them in repair. That it would most essentially advance the strength and prosperity of the whole country, by increasing her exports and the products of her manufactories, and by furnishing employment to a larger number of vessels and seamen. That it would diffuse a spirit of navigation through the very heart of the kingdom, and by bringing many boys and youths from the inland counties towards the sea-port towns, would greatly increase the number of our sailors. That it would find immediate employment, during its construction, for vast numbers of labourers and artisans, and afterwards furnish constant employment to a great many others. And lastly, that it would have a tendency to prevent injurious monopolies of the necessities of life, by opening so extensive and cheap a communication between the interior parts of the kingdom and the manufacturing towns and seaports, that the attempts of the most powerful monopolizers could produce no effect upon the plentiful supply which, by means of canals, could at once be thrown into any market.

The opponents of this measure appear to have been not the landed proprietors on the line, but the companies interested in the competing river navigations. The principal of these were the proprietors of the Weaver navigation, and the lessees of the Burton navigation, which comprised that part of the Trent between Burton and Nottingham. The former of these contended, that as the object of the Grand Trunk Canal was to communicate with Liverpool, and not with Manchester, it was useless to extend it so far as the Duke of Bridgewater's navigation; and that every purpose would be answered by making its termination at Northwich, on the Weaver, and allowing the river below Northwich to remain, as before, the only navigation between Northwich and the Mersey. The parties interested in the Burton navigation raised the usual cry against a competing line running parallel and close to their own, and endeavoured to show that the navigation between Burton and Wilden was so perfect by the river, that there was no need to carry the canal lower down than Burton, which is 16 miles higher up the river than Wilden, where it was proposed to terminate. The arguments used by these interested opponents were singularly weak, being principally directed to show that the proprietors of the new canal would be able, by becoming carriers on their own line, to resolve themselves into monopolists of the worst order; an objection which might, with equal truth, have been raised against the incorporation of themselves, or of any other body seeking power either to construct or to improve any navigation whatever.

Alluding to the great summit of Harecastle, through which it was proposed to carry the canal, this appeared to afford a favourable point of attack. "It is suspected,"

says one of the papers issued by the opposition, "that the projectors do not entertain the chimerical idea of cutting through Harecastle; it is rather believed that they are desirous of cutting their canal at both ends, and of leaving the middle for a future day. Are these projectors jealous of their honour? Let them adopt a clause (which reason and justice strongly enforce) to restrain them from meddling with either until they have finished their great trunk. This, and this alone, will shield them from suspicion." Notwithstanding these triumphant taunts and dark suspicions, the great cutting and tunnel through Harecastle were undertaken with as much alacrity as every other part of the line, affording in that case, as in many a one of later date, the best practical comment upon the absurd and exaggerated statements so commonly put forward by the opponents of really useful measures.

Although the direct distance in a straight line between Liverpool and Hull does not exceed 90 miles, and although the Grand Trunk Canal, far from lying in the straight line, forms, in fact, only part of a horse-shoe navigation, which is more than double the length of the straight line between the two extremities, it must not be too hastily concluded from this, that such a circuitous course was injudicious, and that a more direct line would have been preferable. In reviewing a project of this kind, it is important to bear in mind the objects sought to be effected, and to consider the localities for whose use the work is designed. Now in the present case, the object was not so much to connect Liverpool and Hull, merely as two ports on the opposite sides of the island, and considered merely in reference to each other, as to form between these places a continuous line which should pass through rich and important districts requiring regular communication with each of these ports.

If we take a map of England and examine the circuitous course of the Trent, from Nottingham up to its sources in Staffordshire, we shall find it skirting the southern extremity of the Yorkshire coal field, then passing in succession within a few miles of each of the three several coal fields of Ashby-de-la-Zouch, Tamworth, and Dudley, in addition to passing through a considerable part of the coal field of Staffordshire, and after intersecting this field, ramifying in many directions amongst the potteries of Staffordshire, and finally having its source in the great Harecastle summit, between the counties of Stafford and Chester. Having passed through this rich district, requiring not only an outlet for its natural productions and the manufactures in which its population is engaged, but also facilities of import for raw material and other articles employed in those manufactures, we come next, on the other side of the summit, to the flat plains of Cheshire, which have so long produced in the neighbourhood of the "wiches" abundant quantities of salt, which, being an article of great weight and of immense consumption, stood much in need of a cheap and con-

venient mode of transit. The wiches of Cheshire border the valleys of the Dane and the Weaver, which complete the horse-shoe figure of the Trent in such a way as to present, with the exception of the passage across Harecastle summit, a continuous line of natural stream all the way from Hull to Liverpool.

Now, with respect to the country lying in the direct line between Liverpool and Hull, neither its mineral wealth nor its manufacturing importance bore, at that time, any comparison with those of the districts above described along the valleys of the Trent, the Dane, and the Weaver. Even supposing therefore, for a moment, that which in reality is not the case, namely, that a straight line of canal were practicable at a reasonable expense between these two ports, it would have failed in effecting the purpose for which the navigation was designed, this purpose being to open up rich mineral districts and a busy manufacturing district, and to afford to the whole a ready access to the coast on both sides of the island.

Seeing, then, that the existing rivers of the country pursue that course which leads most directly to the coast from the districts requiring access to the sea, it is obvious that no line of communication could possess equal recommendations with one passing through the valleys of the before mentioned rivers, intersecting, as it necessarily must, all the important districts which border those valleys. The map published by Mr. Brindley, which has been before referred to, gives the following as the lengths and levels of the Grand Trunk Canal:—

	miles. furl. chains.			
From the Duke of Bridgewater's canal at Preston				
Brook to Middlewich*	17	8	0	Level.
Middlewich to Harecastle	12	1	7	316 feet rise.
Harecastle to Haywood	22	5	2	152.11 fall.
Haywood to Wilden Ferry	36	1	0	135.9 fall.
	<hr/>			
	88	7	9	604.8
	<hr/>			

* This statement of lengths is given in Mr. Brindley's own words, but it should be observed that the navigation between Preston Brook and Runcorn Gap, is in reality a part of the Grand Trunk Canal; according to an arrangement made between his Grace and the Grand Trunk Canal Company. It seems that at the time the Act of the latter company was obtained, no progress having been made in the works of the Duke's canal between Preston Brook and the Mersey, it was agreed between the parties that the execution of this part of the canal should be immediately undertaken by his Grace; but that the Act of the Grand Trunk Company should be intitled as follows: "An Act for making a navigable Cut or Canal from the River Trent at or near Wilden Ferry, in the County of Derby, to the River Mersey, at or near Runcorn Gap." These particulars will explain the difference between the length of the Grand Trunk Canal as here stated, and its real length of 93 miles from the Mersey to the Trent. If we add to the 88 miles 7 furlongs, the distance of 5 miles from Preston Brook to Runcorn Gap, the sum will be 93 miles 7 furlongs, the entire length of the Grand Trunk Canal.

The point of junction with the Duke of Bridgewater's Canal at Preston Brook being 79 feet above the Mersey, it will be seen that the whole rise of the Grand Trunk Canal, from the Mersey to its summit at Harecastle, is $316 + 79 = 395$ feet; and its fall, from the summit down to the Trent at Wilden, is $152 \text{ ft. } 11 \text{ in. } + 135 \text{ ft. } 9 \text{ in.} = 288 \text{ ft. } 8 \text{ in.}$ There are 91 locks, 126 aqueducts and culverts, and 6 tunnels on this canal, the principal work being the great Harecastle tunnel, which is 2880 yards in length^a.

We may now examine more in detail the course of the canal, and endeavour to form some estimate of its great national importance, by inquiring into the past and present condition of the country through which it passes, with respect to manufactures and natural productions.

Commencing at the Duke of Bridgewater's Canal at Preston Brook, it passes close to the following places, Northwich, Middlewich, Warrington, Elton, Sandbach, and Lawton, up to the summit at Harecastle. It then passes through the Potteries, near Burslem, Newcastle, Hanley, Stoke, and Lane End; thence along the valley of the Trent, by Trentham, Barleston, Darleston, Stone, Ashton, Sandon, and Shutborough, down to Haywood, where it is joined by the canal from the Severn. Still following the valley of the Trent, the canal proceeds by Bishton, Wolseley, Rudgeley, Wichnor, Drakelow, Burton, Egginton, Weston, and Aston, into the Trent at Wilden Ferry, from which place the Trent itself is navigable by Nottingham, Newark, and Gainsborough all the way into the Humber.

The first great natural productions which are met with on the line of this canal, are the extensive deposits of salt and gypsum, which extend across the plain of Cheshire by Barnton, Northwich, Middlewich, and Sandbach, as far as Church Lawton, where the new red sandstone terminates. No part of this tract, except the immediate neighbourhood of Northwich, had formerly any other outlet for its productions than that afforded by land carriage. The Weaver, which was navigable above Northwich, was used for transporting the salt of Barnton and Northwich into the Mersey; but the districts lying south of these places, were wholly debarred by the expense of land carriage from any thing like competition either with Northwich or Droitwich, which latter place, from its proximity to the Severn, furnished at that time, as it does now, the principal supply of the south of England. From Northwich and Winsford, however, vast quantities of salt were annually carried, at great expense by pack-horses, into all parts of Staffordshire, Derbyshire, Yorkshire, Leicestershire, Nottinghamshire and Lincolnshire. At the time the canal was first proposed, the duty paid to Government

^a This tunnel was entirely reconstructed by Mr. Telford, about 14 years ago. The old tunnel had been formed too narrow for the traffic, and great inconvenience was experienced from the want of a towing path.

by the salt works of Northwich alone, was £67,000 per annum, and the quantity then annually raised at Northwich and Winsford was computed at about 24,000 tons.

The salt mines of this country were worked at a very early period of our history; their produce is mentioned as a source of revenue, 640 years before the Christian era, and it is known that the Romans, who worked the salt mines of Worcestershire, made use of this article as a substitute for money to pay the wages of their soldiers. At Northwich there are two great beds of rock-salt, the first of which lies 130 feet below the surface, and is 75 feet in thickness. Between the two beds is a thickness of $31\frac{1}{2}$ feet of clay, with veins of rock-salt through it, and then comes the second bed of rock-salt, which has been sunk into as deep as 108 feet. Above the salt in this district are numerous layers of gypsum or sulphate of lime, from which plaster of Paris is made, and which is also employed for a variety of useful purposes. The coarser kinds of gypsum are burnt into a rough sort of plaster, which is used for flooring to a great extent in the neighbouring counties. Other kinds, which are more indurated, are used for common rubble walling; and the finer sorts are made into vases, columns, and numerous ornaments which the skill of the turner enables him to produce. Large quantities of gypsum are used in the Potteries for making moulds. The variety which is preferred for this purpose is the pure white gypsum, or that slightly streaked with red; the moulds are made of the plaster produced by burning this kind of gypsum. The importance of this material as a source of employment, has of course been principally developed since the introduction of cheap means of carriage. The price of land carriage in the line of this canal was, on the average, very little under a shilling per ton per mile, the calculations made at the time generally assuming 9s. per ton for 10 miles. The introduction of the canal at once reduced the price of carriage to one fourth of this amount. Salt itself is a still more important article than gypsum, and its use in the arts has been very much extended of late years. In addition to the extensive employment of this article for curing provisions, it has now become a highly important chemical manufacture, known under the name of "British alkali," which has almost superseded the use of foreign barilla, both in the soap and glass manufacture. The refuse salt is used for making soda and its carbonate, while the valuable article called chloride of lime, which is now so extensively used for bleaching, is made from the chlorine produced by the decomposition of salt. Large chemical works are now established in many parts of the salt districts, and several of the works produce weekly from 300 to 600 tons of salt. The employment of both salt and gypsum as a manure has also added to their commercial importance.

Gypsum possesses the property of decomposing ammoniacal salts, which renders it useful for destroying the offensive smell arising from the putrefaction of animal manures.

Its power of converting ammonia into a soluble compound which is not volatile, renders it one of the most valuable dressings which can be placed upon land.

About a mile beyond Church Lawton the canal enters the coal field of the Potteries, and passing through the Harecastle summit, by a tunnel 2880 yards in length, descends by the villages of Tunstall, Burslem, Cobridge, and Hanley, as far as Stoke, where it leaves the Potteries, and again enters the red sandstone formation. The whole of the tract which has just been described from Church Lawton to Stoke, is extremely rich in minerals. In the neighbourhood of Burslem there are 32 beds of coal, varying in thickness from 3 to 10 feet each. The north-western side of this coal field, for several miles north of Harecastle, where the canal enters it, is bounded by the millstone grit on which the coal strata rest. Besides this rock, the range also contains a valuable limestone, freestone fit for building, and several varieties of grinding stones. The principal localities from which all these different kinds of stone have been procured, are the neighbourhood of Congleton and a mountain called Mole Copt, which lies a few miles north of the Harecastle tunnel. In addition to the facilities afforded for transporting these valuable articles throughout the neighbouring counties, the canal has given an immense impetus to the manufacturing industry of the Potteries. The towns of Burslem and Newcastle-under-Line, with the villages of Stoke, Hanley Green, Lanedelf, and Lane End, were even then extensively employed in the manufacture of many kinds of stone and earthenware, which, besides supplying the home consumption, were carried at a great expense to the ports of Bristol, Liverpool, and Hull, and exported to America, to the West Indies, and to many parts of Europe. Before the construction of the canal, the pottery ware destined for Hull had to be carried by land upwards of 30 miles to Willington, and that which was sent to Liverpool was carried by land to Winsford, a distance of 20 miles. Upwards of 400 tons of pot-ware were annually sent by waggons from Burslem and Newcastle to Bridgenorth, thence to be conveyed by water to Bristol; and the waggons brought back foreign iron, China clay, and all sorts of groceries, for the supply of Newcastle, Stafford, Eccleshall, Newport, and the surrounding villages. It was also understood that large quantities of pot-ware were carried on horses' backs, in large crates, to Bewdley and Bridgenorth, from which places they were sent down to Bristol by the Severn.

In consequence of the great burden of such an expensive land carriage, and the uncertainty and delay in the navigation of the Weaver down to Frodsham, of the Trent down to Wilden, and of the Severn below Bewdley, the Potteries were materially suffering at this time from the competition of foreign states, and the opinion had become general that, unless some new and less expensive mode of transit were intro-

duced, the whole of their manufacture which went to supply other countries must have been speedily annihilated by the exertions of France and the United States, both of whom were making rapid strides in improvement. In addition to increased facilities for the export of their wares, the Staffordshire Potteries required then, no less than they do at present, a regular communication with Liverpool and Hull, for the purpose of receiving the raw materials made use of in their manufactures. The gypsum employed as plaster of Paris for making moulds has been already mentioned, and besides this, the China clay brought from Cornwall and Devon had to be conveyed by sea round to Liverpool, and thence up the Mersey and the Weaver to Winsford, the distance from which into the centre of the Potteries, as already mentioned, is not less than 20 miles.

The import of China clay into the Potteries exceeds at this time (1843) 37,500 tons per annum, which being carried from Winsford at a reduction of three-fourths of the price of land carriage, will effect a saving to the Potteries, on this article alone, of more than £25,000 per annum*. Great quantities of flint stones are brought from many parts of the coast to Hull, for the use of the Potteries; these had to be conveyed by water to Willington, and thence by land nearly 38 miles into the Potteries, and they were subject to constant delay from the floods and shallows above Wilden, all of which conspired most seriously to affect the prosperity of this important manufacture. In addition to the regular wares of the Pottery district may be mentioned, the very superior vitrified bricks and tiles which are burnt there, and which have continued in great esteem for building ovens, kilns, and many other purposes, ever since the opening of canals supplied the means of introducing them into other districts.

After leaving the Pottery coal field at Stoke, and passing by Stone and Sandon, through about 18 miles of the marls and clays of Staffordshire, the canal arrives within six miles of the northern extremity of the Dudley or South Staffordshire coal field. The coal mines of Cannock Chase, in this part of the field, although not equal in richness to the southern part of the coal field, as about Dudley and Bilston, contain many beds of coal four, six, and eight feet in thickness. The canal continues its course within a short distance of the coal field, for three miles beyond Rudgeley, when it changes to a more easterly direction. The neighbourhood of Rudgeley is famous for its lime, which is extensively burnt close to the canal. In the estate called Beau-

* Mr. Wedgewood stated, in his evidence before the House of Commons, in 1785, that from 15,000 to 20,000 persons were then employed in the Potteries, and much greater numbers in digging coals for their use. Many thousand persons were also employed in digging flints, and preparing clay, in distant parts of England and Ireland. He estimated the annual import into Staffordshire, of clay and flints, at from 50,000 to 60,000 tons.

desert, which is the property of the Marquess of Anglesea, and which lies within three miles of the canal, forming the north-eastern extremity of the coal field, is procured a famous cannel coal, which is distinguished by the bright and blazing fires it produces, and by its peculiarity of not soiling the fingers, like most other kinds of coal.

The canal continues its course through the new red sandstone, following the valley of the river Trent, till, at Burton, it comes within two miles of the coal field of Ashby de la Zouch. In this field are several valuable seams of coal, one of these being from 17 to 21 feet in thickness. In the neighbourhood of Burton-upon-Trent, are numerous gypsum quarries, at Coton, Marchington, Hanbury, &c., all within a few miles of the canal.

The north-eastern part of the Ashby coal field is flanked by several hills of carboniferous limestone, named Barrow Hill, Cloud Hill, Breedon Hill, and Ticknall. The excellent lime procured from the former of these is well known all over England under the name of the Barrow Lime of Leicestershire; and the lime produced by the neighbouring quarries is of the same quality. The Barrow lime had been famous for many years before the canal was thought of, and was conveyed by land carriage to places at a great distance in many different directions. The canal has of course greatly extended the consumption of this lime, not only for building but for agricultural purposes. In addition to the valuable limestone in the neighbourhood of this coal field, there are excellent quarries of freestone near the bank of the Trent, about a mile below Burton.

From Burton to its termination at Wilden Ferry, the canal continues entirely in the new red sandstone, in which it meets with abundant quantities of gypsum, and a variety of this mineral, which is found at Clay Hill, a few miles below Burton, is extensively used as an alabaster for the purposes of sculpture.

All the coal fields opened up by this canal have derived immense benefit from the importation of Cumberland and other rich ores of iron-stone, by mixture with which the ores of the midland counties have been smelted with great success. The canal has afforded the means of interchanging these ores to an extent which has materially improved the manufacture of iron, and contributed, in no small degree, to the developement of this great branch of national industry.

In addition to the mineral productions which the canal has brought to light, there is a great traffic in corn, timber, charcoal, oak bark, wood, madder, wool, hides, tallow, and many other articles.

By means of canals, which have since been extended from the Grand Trunk towards Birmingham, Wolverhampton, Coventry, Oxford, and London, the former has been the means of supplying Birmingham, Wolverhampton, and other places, with the raw

material used in their manufactures, such as copper, calamine, lead, zinc, ivory, and many others. The Grand Trunk Canal also conveys from Liverpool and Hull, for the use of the midland counties, large quantities of rum, wine, tobacco, sugar, and all kinds of groceries and stuffs, the consumption of which has enormously increased since the introduction of inland navigation. Mr. Wedgewood had the honour of digging the first spadeful of earth for the Grand Trunk Canal, on the 17th of July, 1766.

CANAL FROM THE TRENT TO THE SEVERN.

At various periods in the ten years during which the Grand Trunk Canal was under consideration, the public attention was also called to the project for uniting the Trent with the Severn. Indeed, the two projects must have been at last viewed in intimate connexion with each other, for in the very same session of Parliament (namely, the 6th of George III.) in which the Act was obtained for making the Grand Trunk Canal, another was also passed for making a canal from and out of the former at or near Haywood Mill, in Staffordshire, to the river Severn, between Bewdley and Tipton Brook, in Worcestershire.

This canal lies entirely in the new red sandstone formation of Staffordshire and Worcestershire, and for more than half its course is parallel with the western side of the Dudley coal field, and nowhere more than a few miles distant from the edge of the coal district. The full description which has been given of the natural productions and manufactures on the line of the Grand Trunk Canal will render it unnecessary to go into similar particulars in the present case. It may be sufficient to notice that this canal opened the water communication so much desired between the Potteries and Bristol, and extended the advantages which the Grand Trunk Canal originated to the whole of the South Staffordshire and Dudley coal field. The canal from the Trent to the Severn is now commonly known by the name of the Staffordshire and Worcestershire Canal. It passes through or close to the towns of Penkridge, Wolverhampton, and Kidderminster, falling into the Severn at Stourport, and its length is $46\frac{1}{2}$ miles. From Haywood, where it joins the Grand Trunk, to Aldersley, where it was afterwards joined by the canal from Birmingham, its length is $22\frac{1}{2}$ miles, and its rise 125 feet. From the summit at Aldersley to the river Severn, a length of 24 miles, the canal falls 301 feet. This canal is 30 feet wide at top and 5 feet deep; but the locks, which are 74 feet long and 7 feet wide, were originally made with only 4 feet of water on the sills. The whole number of locks is 44.

With respect to the Grand Trunk and the Staffordshire and Worcestershire canals, both of which were executed under the immediate superintendence of Brindley,

it is much to be regretted that we are absolutely without any means of tracing the progress of the works or of accompanying the engineer through the difficulties and expedients which he had to encounter and contrive. That want of records, journals, and memoranda, which is ever to be deplored when we seek to review the progress of engineering works, is particularly felt when we have to look back upon those undertakings which first called for the exercise of engineering skill in many new and untried departments. In the present case, however, we must content ourselves with regretting that no such things are in existence, and we can only imagine that in addition to the ordinary trials of caution, skill, and judgment, which are called forth by all engineering operations, Brindley must have had many difficulties to contend with which modern practice has been able to reduce to perfect simplicity and ease.

In Brindley's day, the entire absence of experience derived from former works, the obscure position which the engineer occupied in the scale of society, the imperfect communication between the profession in this country and the engineers and works of other countries; and lastly, the backward condition of all the mechanical arts and of the physical sciences connected with engineering, may all be ranked in striking contrast with the vast appliances which are placed at the command of modern engineers.

It may be proper to state here, that the Grand Trunk Canal, which was begun in 1766, was not finished by Brindley, who died in 1772; the canal being completed in 1777, under the management of Mr. Henshall, Brindley's brother-in-law, who has been already mentioned. By far the most active part of Brindley's career must have been comprised in these last six years of his life, a fact which will sufficiently appear from the number of works yet to be mentioned in which he was particularly engaged.

THE DROITWICH CANAL, THE BIRMINGHAM CANAL, AND THE COVENTRY CANAL.

Two years after the first Acts for the Grand Trunk and the Staffordshire and Worcestershire canals were passed, there were three important measures before Parliament, with all of which Brindley was entrusted. These were the Droitwich Canal, the Birmingham Canal, and the Coventry Canal. The first of these, namely, the Droitwich Canal, is a short line of $5\frac{1}{2}$ miles, with a fall of $56\frac{1}{2}$ feet, from Droitwich into the river Severn. The Act for the second is entitled, "An Act for making and maintaining a navigable Cut or Canal from Birmingham to Bilstone, and from thence to Aldersley, there to communicate with the Canal now making between the Rivers Severn and Trent, and for making collateral Cuts up to several Coal Mines." The third

project also obtained the sanction of Parliament under the following title, "An Act for making and maintaining a navigable Canal from the City of Coventry to communicate upon Fradley Heath, in the County of Stafford, with a Canal now making between the Rivers Trent and Mersey."

The following are the lengths and levels of these canals as laid out by Brindley :

DROITWICH CANAL.

	miles.	furl.	chains.	feet.	in.
From Droitwich to the river Severn	5	4	9.23	56	6 fall.

THE BIRMINGHAM CANAL.

	miles.	furl.	chains.	feet.	in.
From Birmingham to Smithwick	6	2	0	36	0 rise.
From Smithwick to junction of Wednesbury Branch	0	6	0	18	0 fall.
From junction of Wednesbury Branch to the Trent and Severn Canal, at Aldersley	13	4	0	118	0 fall.
Wednesbury Branch to coal mines	3	6	0	18	0 fall.
	<u>24</u>	<u>2</u>	<u>0</u>	<u>190</u>	<u>0</u>

THE COVENTRY CANAL.

	miles.	furl.	chains.	
From Coventry to Atherstone	14	4	0	level.
From Atherstone to Tamworth	9	2	6.90	95 ft. fall.
From Tamworth to the Trent and Mersey Canal	11	5	2.24	level.
Branch to Arbury	0	5	0	level.
Branch to coal mines at Stoke	0	6	9.70	level.
	<u>36</u>	<u>7</u>	<u>8.84</u>	<u>95 feet.</u>

The Droitwich Canal was wholly executed by Brindley, and its works are considered superior to those of any others in which he was engaged. Coal and salt are the principal articles of traffic on this canal, the former being taken up the canal out of the Severn, and the latter exported from the extensive salt works in the neighbourhood. The original capital of the company was £33,400 in shares of £100 each,

with power to raise a farther sum of £20,000. The canal has for many years continued to be a highly profitable concern, and so high a price had the shares attained when the Worcester and Birmingham Canal was proposed in the thirty-first year of George III., (1791,) that the proprietors of the latter are bound in their Act to make compensation to the Droitwich Canal Company for any diminution which may be made in the profits of their concern*; and in order to estimate this diminution each share is to be taken to be of the value of £160, and the then profit of each such share is to be taken at five per cent. per annum.

The Birmingham Canal was only partially executed by Brindley; after his death it fell into the hands of his former pupil, Mr. Whitworth. The services of Smeaton were on several occasions called in by the proprietors, and great improvements were made by the late Mr. Telford. It will be observed, on referring to the statement above given of the lengths and levels of this canal, that it was originally laid out with a rise of thirty-six feet from Birmingham to the summit; and from this summit to the Trent and Severn Canal the descending lockage is 136 feet. The canal was accordingly executed with these levels by Brindley and his successor, Mr. Whitworth, and the summit level at Smithwick, which was only a mile in length, was for many years supplied with water pumped up by two steam engines erected for the purpose. About the year 1784, however, the Company decided upon lowering this summit level to the extent of eighteen feet, and this improvement was accordingly executed, to the great benefit of the navigation. It would seem that Brindley was in no way to blame for the error committed in this canal with respect to the Smithwick summit, as he strongly advised the Company to carry the canal, by means of tunnelling, on a lower level, in order to avoid the expense of lockage and pumping power. Soon after the opening of the canal, the Company had reason to regret their rejection of Mr. Brindley's advice, and at length they repaired the error by lowering the summit at a cost of about £30,000. The Birmingham Canal Company was empowered under their Act to raise the sum of £55,000 by shares of £100 each, and a further sum of £15,000 if required.

The Coventry Canal, as laid out by Brindley under the Act of the eighth George III., commences by a junction with the Grand Trunk Canal at Fradley Heath, from which place it takes a southerly course to Huddlesford, and passes by Hopwas on to Fazeley, near Tamworth, where the Birmingham and Fazeley Canal locks down into it. From Fazeley the canal pursues a north-eastwardly direction, crossing the river Thame and passing by Amington. Hereabouts the direction changes nearly to

* Priestley's Historical Account of the Navigable Rivers, Canals, and Railways throughout Great Britain. London, 1831.

the south-east, the canal running parallel with the river Anker, and afterwards passing by or near to Polesworth, Atherstone, Hartshill, Nuneaton, and the villages of Bedworth and Longford to the city of Coventry, where it terminates*. The Coventry Canal Company was empowered by its Act, already mentioned, to raise the sum of £50,000 in shares of £100 each, and they had also power to raise, if required, the additional sum of £30,000 by creating new shares. It appears that during Brindley's lifetime, and under his management, the original capital of the company, that is the £50,000 mentioned above, was expended on the first fourteen miles, from Coventry to Atherstone, and as it was found impracticable to raise the additional £30,000 mentioned in the Act, the completion of the canal was delayed for many years. It appears that Brindley gave up the management of the Coventry Canal in consequence of a dispute between himself and the Company, and although we have no direct authority for connecting this fact with the insufficient estimate on which it appears to have been undertaken, there is certainly a strong temptation to view the obvious error of estimating a canal thirty-six miles in length at a sum which was found barely sufficient to execute the first fourteen miles of it, as in some degree the cause of the misunderstanding.

Whether this be so or not, it should never be forgotten, that alike in the full career of successful practice, and in the years of early struggle to rise into future eminence, the first duty of the engineer is that of laying before his employers sound and honest information as to the cost of the works. To perform this office faithfully, no matter what disappointment it occasions in the first instance, is to secure for himself the esteem and confidence of all around him ; to neglect it, is most surely to injure his reputation, and to call down the indignation, and it may be the contempt, of those who first listened to the incautious announcement which sacrificed truth to the desire of pleasing, or perhaps to some less worthy motive.

The original company of proprietors of the Coventry Canal was never able to carry it into effect, and as the completion of the project was known to be of great importance as part of the communication between London and the Grand Trunk Canal, two other companies undertook, in 1785, to complete the Coventry Canal between them. These companies were the proprietors of the Birmingham and Fazeley Canal, which had been executed in the mean time, and the proprietors of the Grand Trunk, who successively went to Parliament in the twenty-fifth and twenty-sixth years of George III. for powers to complete the Coventry Canal. With respect to this canal, Mr. Priestley observes, "it was a part of Mr. Brindley's scheme for

* Priestley's Historical Account of the Navigable Rivers, Canals, and Railways throughout Great Britain. London, 1831.

completing an inland navigation between the ports of London, Liverpool, and Hull, and now that that object is effected, its revenue is derived chiefly from cargoes passing between those places, as will appear from the circumstance that shortly after the completion of the Oxford Canal, the original shares were quadrupled in value, and have since that period considerably advanced."

THE OXFORD CANAL.

The year after Acts were obtained for the three measures which have just been described, we find another important Bill before Parliament, under which powers were sought to make a canal from Oxford to the Coventry Canal, at Longford. Mr. Brindley laid out this canal, and appeared in support of it before Parliament, and had the satisfaction to witness the passing of the Act for its construction in the ninth year of George III.

The following are the lengths and levels of this canal * as laid out by Brindley :

	miles.	furl.	chains.	
From Longford to Brinklow	10	7	8.35	level.
Brinklow to Hillmorton	9	1	2.60	level.
Hillmorton to top of Napton Field	17	1	4.78	88 feet rise.
Top of Napton Field to Claydon	8	5	0.97	level.
Claydon to Banbury	6	4	8.40	88 feet fall.
Banbury to Oxford	29	3	8.72	116 feet fall.
	<hr/>	<hr/>	<hr/>	
	82	7	3.82	292
	<hr/>	<hr/>	<hr/>	

The levels, however, were considerably altered during the construction of the canal after Brindley's death, and a great number of Acts have been obtained from time to time authorizing the proprietors to make improvements by taking out the bends and making new cuts in the line of the canal. The original capital of the Oxford Canal Company was £178,648. The canal is twenty-eight feet wide at top, sixteen at

* In Mr. Priestley's account of this canal there is an erroneous statement as to its levels. The height at its junction with the Coventry Canal is said by him to be $315\frac{1}{2}$ feet above the level of the sea, and the whole rise to the summit is stated at 74 feet. This would make the height of the summit level $389\frac{1}{2}$ feet above the sea. Mr. Priestley further gives the fall from the summit down to Oxford at 77 feet, and adds, that at Oxford the termination of the canal is 192 feet above the sea. Now if we deduct 77 feet from $389\frac{1}{2}$ we shall have, according to the levels here given, the height at Oxford = $312\frac{1}{2}$ feet, being more than 100 feet in excess of the real height at Oxford, supposing that height of 192 feet to be, as we believe it is, very near the truth. Mr. Priestley appears to have omitted the fall of 116 feet from Banbury to Oxford, which would make the levels nearly agree with Mr. Brindley's.

bottom, and four and a half feet deep. It has forty-two locks, with an average lift of nearly seven feet. On the summit level the Claydon tunnel is 1188 yards in length.

THE CHESTERFIELD CANAL.

This canal, which is 46 miles in length, extending from Chesterfield to the river Trent at Stockwith, is the last great work projected by Brindley, for which an Act was obtained during his lifetime. The canal was chiefly designed for the export of coal, lime, and lead from the mineral districts of Derbyshire, and of iron from the furnaces in the neighbourhood of Chesterfield. The trade from the Trent consists of the corn, deals, timber, groceries, &c., which are conveyed into Derbyshire.

At the time when he projected this canal, in 1769, Mr. Brindley stood probably at the head of his profession. But he had also rivals of great ability, who became afterwards in their day almost as celebrated as Brindley himself. Among the foremost of these were Smeaton, who has been already mentioned, and John Grundy, who afterwards executed many considerable works, not to mention Whitworth, who at the time we speak of, was a pupil of Brindley's. It appears that Grundy was consulted on the subject of the Chesterfield Canal, and that he proposed a plan widely different from that of Brindley. The latter appears to have viewed straightness of direction as an object of no serious importance; and he certainly fell in with, if indeed he did not originate, the prevailing opinion of that day, that a circuitous course was almost justifiable and beneficial in the case of a canal, considering that in such a course it touched upon more places, and gave greater facilities of communication, than a straight line possibly could.

The Chesterfield Canal, as laid out by Brindley, was accordingly as crooked as the Grand Trunk, the Oxford Canal, and most of his other lines. Grundy, however, took another view of the subject, and came forward as the advocate of a nearly straight line of canal from Chesterfield. The line he proposed was nearly $5\frac{1}{2}$ miles shorter than Brindley's, and his estimate was £71,479, while Brindley's estimate was £94,908. It is impossible to judge, at this distance of time, as to the relative correctness of the two estimates. It would seem, however, that the promoters of the undertaking could not have placed implicit confidence in Mr. Grundy, for notwithstanding the advantage his line presented in point of direction and apparent economy, they decided upon adopting the line proposed by Brindley, and accordingly obtained an Act for making a navigable cut or canal from Chesterfield, in the county of Derby, through or near Worksop and Retford, to join the river Trent at or near Stockwith, in the county of Nottingham.

There is another reason for adopting circuitous lines of canal in the first instance, which may have had some weight with the companies which were formed in the infancy of the science, and which it may not be out of place to mention. A circuitous line will, under most circumstances, cost less per mile to construct than a straight line, and as the tonnage is charged by the mile, it is obviously an advantage to the proprietors to possess a *cheap long line* of canal rather than an *expensive short one*; it will readily be seen that, *cæteris paribus*, the former will pay much better than the latter.

The Chesterfield Canal has several very heavy works, the principal of which is the summit tunnel, 2850 yards in length. This tunnel, which lies between the villages of Wales and Harthill, is $9\frac{1}{4}$ feet wide and 12 feet high. The rise of the canal from the Trent to its summit is 335 feet, and it falls 45 feet from the summit down to Chesterfield. There are 65 locks, and besides the summit tunnel, there is one at Gringley Beacon 153 yards in length.

Mr. Brindley superintended this canal till his death in 1772, and the works were then continued by his brother-in-law, Mr. Henshall, and completed by him in 1776. That part of the canal between the Trent and Retford, is constructed for vessels of 50 to 60 tons burthen. The remaining part is only intended for boats of about 20 tons. Up to the year 1789 the canal had cost £152,400, and at that time the dividend was only 1 per cent. Sixteen years afterwards, however, a dividend of 6 per cent. was divided, and up to 1831, when Mr. Priestley's account was published, he states that the undertaking had been gradually improving.

Such are the principal works in the actual execution of which Mr. Brindley was engaged. With respect to the numerous projects in which he was consulted, some of which were afterwards executed and others abandoned, it would occupy too much space to give a particular account of each; we shall therefore add merely a list of the principal of these, with such brief explanations as appear to be necessary.

THE LEEDS AND LIVERPOOL CANAL.

This great undertaking, which was at first placed under the management of Mr. Longbotham, and which has engaged the talents of Whitworth and many others of the first engineers in this country, deserves to be ranked as something more in connexion with Brindley than a mere project on which he was incidentally consulted. He it was in fact who surveyed and laid out the whole line of the canal, and who framed the estimate on which the company went to Parliament to obtain their Act. The canal, according to Brindley's survey and estimate, was to be $108\frac{3}{4}$ miles in length, 42 feet wide at top, 27 feet at bottom, and 5 feet deep, and was to cost

£259,777. This estimate, however, was far exceeded, the actual cost having amounted in the whole to about £1,200,000: but it should be noticed that, in consequence of the long time during which the canal was in hand, the monetary standard of value had greatly increased towards the end of the period when the canal was finished in 1816, no less than 46 years after its commencement. There are some truly gigantic works on this canal, amongst which are the great Foulridge tunnel, several embankments upwards of 60 feet high, numerous large aqueducts, two reservoirs which cover 144 acres of land, and a suite of five locks at Bingley, which together effect the enormous lift of 89 feet. At the first general meeting of the proprietors after the passing of the Act of Parliament, Brindley was appointed engineer to the company; but in consequence of the great number and importance of his other engagements, he was obliged to decline this appointment.

The Leeds and Liverpool Canal yields in importance to no other canal in Great Britain. Like the Grand Trunk, it connects the Irish Sea with the German Ocean, and passes through some of the most wealthy and populous scenes of manufacturing industry. It is understood to be a highly profitable speculation.

CANAL FROM SUNNING TO MONKEY ISLAND.

Mr. Brindley was engaged, as well as Smeaton, Whitworth, and others, in several projects originated by the Corporation of London for the improvement of the Thames navigation, by constructing canals for a considerable part of the distance between London and Reading. These measures produced several able surveys of the river Thames, which are highly valued by engineers, and are frequently referred to at the present day, but were all abandoned when the Grand Junction Canal was undertaken. This canal, which joins the Thames at Brentford, and connects it with the Oxford Canal, removed a great part of the trade between Brentford and Reading, and now that the Great Western Railway has established a far more perfect communication than either that of the river or canals, it is probable that no more will ever be heard of canals between Richmond and Reading.

Application was, however, made to Parliament during the lifetime of Brindley, for an Act to make a canal from Sunning, near Reading, to Monkey Island, near Richmond, but the project was defeated by the opposition of the landowners.

THE CALDER NAVIGATION.

This work, on which Mr. Smeaton was originally employed in 1757, is said, in the *Biographia Britannica*, to have been for some time under the management of Mr. Brindley, who declined a further inspection of it, on account of a difference in opinion

amongst the Commissioners. In 1766, Mr. Brindley laid out a canal, which has since been executed, from Huddersfield to the river Calder, at Cooper's Bridge.

CANAL FROM STOCKTON TO WINSTON.

This canal was planned in the year 1768, but never executed. Its necessity is now superseded by the Stockton and Darlington Railway.

CANAL FROM LEEDS TO SELBY; CANAL FROM THE BRISTOL CHANNEL, NEAR UP-HILL, IN SOMERSETSHIRE, TO GLASTONBURY, TAUNTON, WELLINGTON, TIVERTON, AND EXETER; CANAL FROM LANGPORT, SOMERSETSHIRE, BY WAY OF ILMINSTER, CHARD, AND AXMINSTER, TO THE BRISTOL CHANNEL AT AXMOUTH.

These projects were surveyed and reported on by Mr. Brindley in 1769, but neither has yet been executed. The towns of Leeds and Selby are now connected by a railway, and the navigation of the river Exe, which runs nearly in the line of Brindley's canal, has been greatly improved by the works executed under the direction of Mr. Green, about ten years ago.

THE ANDOVER CANAL, FROM ANDOVER, IN HAMPSHIRE, TO REDBRIDGE, NEAR SOUTHAMPTON.

Mr. Brindley laid out this canal in 1770, but the Act of Parliament was not obtained till 1789, when its execution was entrusted to Mr. Whitworth. Its principal trade is the importation of coal and groceries, and the export of agricultural produce.

SALISBURY AND SOUTHAMPTON CANAL.

This work was laid out by Mr. Brindley in 1771, and many years after his death a company was formed and two Acts of Parliament obtained for its execution, in 1795 and 1800. Considerable progress was then made with the works, but in consequence of imperfect puddling, or of the entire neglect of this precaution, the canal would not hold water, whereupon the whole project was abandoned, and has never since been revived. The only complete part of the canal is that along the bank of Southampton Water, between Southampton and Redbridge, where it joins the Andover Canal.

THE LANCASTER CANAL.

In 1772, Mr. Brindley surveyed the part of this important navigation, which lies between Preston and Lancaster; and after his death, Mr. Whitworth completed the survey to Kendal, in Westmoreland. The project was resumed in 1791, and the first Act obtained by the proprietors in 1792. It extends from Kendal, by the towns of Lancaster and Preston, to the Leeds and Liverpool Canal, at Johnson's Hillock, a distance of 11 miles from Liverpool.

The Lancaster Canal is interesting as the first great work on which the late Mr. Rennie was engaged. His celebrated aqueduct for carrying the canal across the river Lune at a height of 51 feet above the river, which is crossed by five arches of 70 feet span each, is a work of great magnitude, and deservedly ranks as one of the highest engineering achievements of that day.

CANAL FROM RUNCORN TO LIVERPOOL.

Mr. Brindley intended this canal to cross the river Mersey by an immense aqueduct near Runcorn Gap, and to proceed to Liverpool on the north shore of the Mersey. The canal has not been executed.

CANAL FROM CHESTER TO THE GRAND TRUNK.

The line which Mr. Brindley surveyed was probably that of the Ellesmere Canal from Chester to Nantwich, with a branch to the Grand Trunk at Middlewich. By the first Acts of Parliament obtained for this canal the proprietors are empowered to make it from Chester to Nantwich and Middlewich. In the Act 17th George III., 1777, however, there is a most singular clause inserted for the protection, as it is called, of the Duke of Bridgewater and the Grand Trunk Canal Company, by which the Chester Canal Company is restricted from carrying the Middlewich branch of that canal nearer than 100 yards to the Grand Trunk Canal. In consequence of this restriction the branch to Middlewich remained untouched up to the year 1827, while in the mean time the Chester Canal had been extended to the south as far as Wolverhampton, and connected, at Welshpool and several other places, with the Severn, and with the canals in Staffordshire. The want of a communication with the Grand Trunk, however, was still severely felt, and a valuable mining district in Denbighshire was almost ruined by the competition of places more favoured by the proximity of water carriage. At the same time the value of the shares in the Chester Canal had been extremely depressed by the want of communication with other canals, and at one time were worth no more than one per cent. of their original value. In 1827, however, the influence of the Chester and Ellesmere Canal Company was sufficiently strong to effect a junction with the Grand Trunk at Middlewich. Under the powers of an Act obtained in that year the Grand Trunk Company undertook to cut a branch of 100 yards in length out of their own canal, and by another Act passed in the same year the Chester and Ellesmere Canal Company is empowered to make a cut of five miles to join this branch from the Grand Trunk. In this way these important navigations have been united, we believe greatly to the advantage of both, notwithstanding the long and determined opposition of the Grand Trunk Company.

THE FORTH AND CLYDE CANAL.

Mr. Smeaton was originally employed in laying out this canal, and when Brindley was called in to revise the plans, his opinions appear to have been considerably opposed to those of Smeaton. The latter, however, was appointed engineer, and under his management, and that of Mr. Whitworth, who succeeded him, this great work was completed.

BRIDGE FROM PORTPATRICK TO DONAGHADEE.

We know nothing of this project, except that it was said to have been a very favourite scheme of Brindley's, and was to have been effected "by a floating road and canal, which he was confident he could execute in such a manner as to stand the most violent attacks of the waves."*

CANAL FROM CHESTERFIELD BY WAY OF DERBY TO THE GRAND TRUNK AT SWARKESTONE.

This has not been executed.

Besides these numerous projects, the consideration of which must have required the active and incessant occupation of Brindley's time and talents, there are many brief notices of his inventions and casual employments scattered through the imperfect histories of his life. Amongst these may be noticed his suggestions for the drainage of the fens in several parts of Lincolnshire and the Isle of Ely; his plan for cleansing the Liverpool Docks of mud; his method of building walls against the sea without mortar; his improvements in the machinery for raising water and coals out of mines; his use of double barges with an opening between them for forming canal embankments, on the principle of the hopper barge, with several others, concerning which we are merely in possession of notices like the above, without particulars of any kind.

Mr. Brindley died in the fifty-sixth year of his age, at Turnhurst, in Staffordshire, on the 27th September, 1772, and was buried at New Chapel, in the same county.

PROFESSIONAL CHARACTER OF BRINDLEY.

In taking a hasty retrospect of Brindley's engineering career, it is important to remember that all the works he projected, planned and executed, are comprised within a period of twelve years, and by far the greater part of them within the last seven years of his life. It is amazing to reflect that the man who had to struggle, without

* Morning Post, August, 1776.

precedent or experience to guide him, with all the difficulties which attended the early history of canals, should himself have effected and originated so much. There can be no doubt that he possessed an intellect of the highest order, that his views were most comprehensive, and his inventive faculties extremely fertile. Brindley was wholly without education, and it has even been asserted that he was unable to read and write, the utmost extent of his capacity in the latter accomplishment extending no further than that of signing his name. This, however, has been disputed, as before mentioned, on the authority of his brother-in-law, who stated that he could both read and write, though he was a poor scribe. However this may be, it is certain that he was quite ignorant in the vulgar sense of the word Education, and perfectly unacquainted with the literature of his own or any other country. It may be a bold assertion, and yet I believe it to be one with strong presumptions in its favour, that Brindley's want of education was alike fortunate for himself, for the world, and for posterity. There was no lack of scholars in his day more than in our own; nay, the literary coxcomb had then a more flourishing soil in which to vegetate. But where were the Brindleys amongst these scholars; where were the men capable of the same original and comprehensive views, the same bold unprecedented expedients and experiments upon matter and the forces of nature, which the illiterate Derbyshire ploughboy dared to entertain and to undertake? If we range the annals of the whole world, and include within our survey even those examples in sacred history where divinely appointed ministers were raised to work out great designs, we shall find no instance more remarkable nor one which more completely violates the ordinary expectations and probabilities of mankind, than this in which the uneducated millwright of a country village became the instrument of improving beyond the bounds of sober belief the condition of a great nation, and of increasing to an incredible amount her wealth and resources. But it may be asked, Why would Brindley have been less fit or less likely to accomplish all he did, if at the same time he had been educated? The answer to this is, that a mind like Brindley's would have lost much of its force, originality, and boldness, if it had been tied down by the rules of science, his attention diverted by the elegancies of literature, or his energy diluted by imbibing too much from the opinions of others. Alone he stood, alone he struggled, and alone he was proof against all the assaults of men who branded him as a madman, an enthusiast, and a person not to be trusted. Who dare assert, if Brindley could himself have wielded the weapons of paper warfare, and himself have sounded the note of eloquent declamation, that he might not have been beguiled to waste his strength and talents in the most inglorious of combats, and have applied those energies to refute upon paper that which he did most amply refute under the canopy of the open heaven, upon the broad face of creation, upon the waters, and

upon the earth? Who would exchange the career of Brindley for that of the noiseless bookworm, the blustering pedagogue, or the vaunting orator? Brindley has become himself a subject for contemplation instead of a mere medium through which men look towards something greater; a topic to arrest and command attention, not the mere instrument to point out something else which is worthy of such attention; a being whom men regard with wonder and admiration for his own deeds and for his own sake, not for the expression of borrowed sentiments, however enthusiastically conceived or loftily delivered. Let no one, therefore, regret that Brindley was uneducated in the learning of books and of the schools. He was a true disciple of nature. In the language of creation he was deeply read, and I question whether he who could imagine and execute such noble projects may not with justice be called one of the most highly educated men whom the world has ever produced. It was fortunate for Brindley that the vigour of his mind was allowed to employ itself in carrying into effect his great designs, rather than in attaining the art of communicating those designs to others, who would perhaps have passed them by unheeded till long after he had ceased to live. It has happened, and in our own times too, that a master spirit not inferior to Brindley, like him a child of nature, like him at first uneducated and of low degree, and with an intellect teeming with lofty and noble enterprise, has mastered all the difficulties of early neglect and abject poverty of birth, and taught himself the art of discoursing by his pen in strains of learned and most magically pleasing eloquence. If the reader would know with what success he thus wrote, the answer is, that although he continued the slave of his ever active intellect, and of his urgent pecuniary necessities, and wrote up to the very hour of his death, yet he died in penniless misery. I dare affirm, and there are some in the profession of engineers who know the man I mean, and who will bear me out in this, that if the services of this individual had been purchased by the government of any country in the world, and his unmatched abilities and profound acquaintance with nature had been allowed free exercise, he would have raised that country to a higher pitch of greatness than any statesman or legislator who has ever been intrusted with the fortunes of a nation.

When I contrast the fate of this equally great genius with that of Brindley, I cannot help repeating that ignorance of books was probably a fortunate circumstance in his case; for if a mind like his had become accessible to the charms of literature and science, we might have had volumes which his contemporaries would have ridiculed and trampled upon, which posterity might, perhaps, have cherished, or perhaps not; but in that case we should certainly not have had to regard Brindley as the boldest leader in engineering enterprise, and the most successful and talented of all those who have laboured in the same honourable path. The great difference

between Brindley's era and our own must not, however, be forgotten. The literature of most European countries abounds with very valuable records of engineering works, and an acquaintance with these works is absolutely necessary to every one who would practise with credit and success. The modern engineer is enabled, by means of book education, to lay in a vast stock of experience, and to make himself master of much valuable scientific knowledge. In Brindley's day it was far otherwise; for there were few books which could have taught him that which he stood in need of, and education would only have given him weapons with which to oppose and foil his scribbling assailants. He was better without such weapons, for as it was, the shafts of his opponents fell harmless upon him; he who could not or would not read must have been impenetrable alike to the ridicule and arguments of those who dealt only in wordy warfare; and so he pursued the unbroken tenor of his way, conscious and confident of his own powers, little affected, either for good or evil, by the machinations of his contemporaries.

In maturing his designs and in working out their details, Brindley appears to have had a way peculiar to himself, and one which those of inferior abilities would find very difficult of imitation. It is said that he rarely or never had any drawings made, even of his most difficult and complex works; but that he was accustomed to frame and arrange the whole in his head without the aid of diagrams or palpable representation of any kind. For the purpose of quiet and uninterrupted thought and communion with himself, it is said that he was in the habit of retiring to bed, where he remained sometimes for several days together, and when at length he rose from this long reverie, he was completely master of every proportion and arrangement of every part of the whole subject which he had been considering; and could execute or cause it to be executed without a drawing or model of any sort. A power analogous to this was that which he possessed of being able to impress upon his mind the whole composition, arrangement, and construction of the most complex machine without the aid of any memoranda or sketches, provided he had time enough allowed to make an examination satisfactory to himself. The same faculty of extensive comprehension and mental concentration was displayed in his method of calculating: he would work in his head a long and complicated process of figures, and set down upon paper only the result of these, and then continue the process in his head till he had completed a further stage. In this way he arrived at the end, and it is said that his results were generally accurate; a fact which astonished those who knew not the power of such a mind, and who expect every thing to be done by the rules which are followed by the generality of mankind.

There are a few personal anecdotes of Mr. Brindley which have invariably been

inserted in every account of his life, and which must therefore be so familiar to many of our readers as not to require repetition. Amongst the most famous of these is the well known answer which he gave to a committee of the House of Commons, when asked what was the use of rivers? "To feed navigable canals," said Mr. Brindley, with an enthusiasm in favour of his own absorbing enterprises which carried him beyond the more enlightened and not less comprehensive views which a more philosophical judgment would have suggested. Brindley's answer, however, rash and enthusiastic as it may seem, was probably correct enough with reference to the object which was then engaging the attention of the committee, namely, the adaptation of rivers to the purposes of navigation. Supposing it had been asserted, as it probably had, that rivers in this country were not adapted by nature to serve the purposes of navigation, the question would naturally arise, "Of what use, then, are rivers with reference to navigation?" "To feed canals," said Brindley, which latter being supplied with the water from rivers, can be so constructed as to be navigable with equal facility in every direction.

The late Mr. Rennie was in the habit of telling an anecdote^a of Brindley, which is interesting from the association by which it recalls the memory of the engineer, and that of his noble friend and patron, struggling with the pecuniary embarrassments attending on the great project in which he had embarked. This anecdote was received by Mr. Rennie from a Mr. Bradshaw, who lived at Worsley Hall, and who was on terms of intimacy with the two great men—the Duke and his engineer—who were then engaged in forming the Bridgewater Canal. On one occasion, when the financial difficulties of the Duke had reached their highest point, it happened that his Grace, with Mr. Brindley and Mr. Bradshaw himself, assembled, as they were in the habit of doing, at a village alehouse near Worsley Hall, for the purpose of friendly chat; and it may be supposed that at such a time the affairs and prospects of the canal would form a prominent topic of their thoughts. We are told that the three sat for some time smoking their pipes in silence, and the Duke was observed to be unusually depressed and melancholy, musing, it might be, over the fortunes of his darling project, and balancing his own ardent anticipations against the cold discouraging voice of public opinion, when Brindley suddenly started up and exclaimed with great animation, "Don't mind, Duke, let us not be cast down, we shall be sure to succeed." Mr. Bradshaw long remembered the impression made by the earnest and almost prophetic manner of Brindley, and by his sudden interruption of the silence and gloom which had hung over the party. It may be that to mutual exchanges

^a Obligingly communicated by George Rennie, Esq.

of cheering counsel such as this, the ultimate triumph of their great project was mainly owing.

Mr. Vignoles, who, from the extensive works he has executed in that part of the country, must be well acquainted with the localities, has been good enough to describe Worsley Hall, the residence of old Bradshaw, as a conspicuous object on the hill north of the canal at the village of Worsley. "The house overlooked Chatmoss, and is, or was, very conspicuous from the Liverpool and Manchester Railway. Lord Francis Egerton, however, is building a magnificent new mansion of stone lower down the hill, and it was understood that old Worsley Hall was to be pulled down."

In addition to the answer given about the use of rivers, several other anecdotes which are related of Brindley arose out of his examination before committees in Parliament. It is said that when in his evidence he was making frequent use of the expression "*puddling*," and describing its use and advantages; some of the members were anxious to know what *puddle* really was, and what kind of a composition it was that Brindley intended to apply to so many and to such important purposes. The engineer characteristically preferring illustration to an abstract description, caused a mass of clay to be brought into the committee room, and moulding it in its raw untempered state into the form of a trough, poured into it some water, which speedily ran through and disappeared. He then worked the clay up with water to imitate the process of puddling, and again forming it into a trough, filled it with water, which was now held in without a particle of leakage. "Thus it is," said Brindley, "that I form a water-tight trunk to carry water over rivers and valleys wherever they cross the path of the canal."

The following anecdote relating to the Barton Aqueduct over the Irwell, mentioned in an earlier part of this memoir, has been obtained through the kindness of James Loch, Esq., M.P., and is less known than some of the preceding. When asked by the committee to produce a drawing of the proposed bridge or aqueduct, he said that he had no delineation of it on paper, but he would represent his intentions by a model. He then went out and bought a large Cheshire cheese, which he brought into the room and divided into two equal parts, saying, "*here is my model.*" We are not told in what way he made the cheese to illustrate the construction of the aqueduct, but it is probable that he might have erected the two halves at a little distance apart from each other, so as to represent one of the semicircular arches of the aqueduct, and then laying any long rectangular object over the top of the two half cheeses he could readily make any one understand the position of the river flowing underneath and the canal passing over it. The model appears to have afforded some amusement,

and to have answered its purpose, for Brindley was requested to leave it with the committee that they might have it before their eyes during the progress of their inquiries.

Brindley, like all others who have ever distinguished themselves as engineers, was enthusiastically attached to his profession, and had no taste for ordinary amusements, nor for pursuits which were not in some way connected with it. It is said that on one occasion he was prevailed upon, when in London, to go to a theatre. So new was the scene, and so much did the performance engage his attention, that he declared it unsettled his ideas for several days, and rendered him so unfit for business that he would never consent to repeat his visit. He is thought by many to have shortened his life by his excessive application to business; and he has been blamed for undertaking simultaneously so many vast projects that the time of no one person could possibly do justice to them all. Those who have censured him in this respect have probably not reflected how extremely difficult or impossible it would have been, in his circumstances, to refuse the management of great works whose success was almost thought to depend upon the exercise of his abilities. We may be sure that not only were employments of the most lucrative kind thrust upon him, but that his refusal to accept a particular engagement would have been a source of offence, and would have been deeply lamented as a serious injury to the prospects of the concern.

We have no reason to suppose that Brindley ever visited any foreign country; on the contrary, he is said to have refused an invitation from the King of France to go over there to see the great canal of Languedoc. Brindley's answer was, that "He would have no journeys to other countries unless it were to be employed in surpassing what was already done in them." The anecdote which has been told of Brindley when asked for what use rivers were created, was first published in the *Morning Post*, in August, 1776. The author of this anecdote adds the following assertion, which has been completely contradicted by others:—"Clear as his head must have been, he had, in delivering his opinion, so unmeaning and poor a way of expressing himself, that he was taken by many for an idiot." The author of his life in the *Biographia Britannica* observes, in contradiction to this, "He was so far from looking like an idiot, that he had an animated and sensible countenance."

The wonder and admiration with which Brindley was regarded when in the zenith of his career, may be gathered from the following expressions taken from the letter of a correspondent, which appeared in a newspaper of 1767, when the Grand Trunk Canal was in progress:—"Gentlemen come to view our eighth wonder of the world, the subterraneous navigation, which is cutting by the great Mr. Brindley, who handles rocks as easily as you would plum pies, and makes the four elements sub-

servient to his will. He is as plain a looking man as one of the boors of the Peak, or one of his own carters ; but when he speaks, all ears listen, and every mind is filled with wonder at the things he pronounces to be practicable."

We are absolutely without any information whatever relating to Mr. Brindley's domestic history. His disposition appears, however, to have been extremely amiable, and his mind entirely free from jealousy and contracted notions of any kind. He affected no concealment of his plans and methods of proceeding, and never took out a patent for any one of his inventions. "Sensible," says a contemporary writer*, "that he must one day cease to be, he selects men of genius, teaches them the power of mechanics, and employs them in carrying on the various undertakings in which he is engaged." The same writer describes him as very ready to assist and advise inventors and workmen engaged on difficult machines, where his great mechanical skill is of immense service. "His powers shine the most in the midst of difficulties. When rivers and mountains seem to thwart his designs, then appears his vast capacity, by which he makes them subservient to his will."

* History of Inland Navigations, London, 1769.



MEMOIR OF WILLIAM CHAPMAN.

WILLIAM CHAPMAN, Esq., M.R.I.A., Civil Engineer, was born at Whitby, of a respectable and opulent family, which had been settled in that town for several generations. Mr. Chapman inherited the freedom of Newcastle-upon-Tyne from his father, who, in common with all the chief people of Whitby, was engaged in shipping, and who was, besides, particularly distinguished by his attainments in mathematics and other scientific pursuits. The scientific habits of the father proved of great service to the subject of this memoir, who imbibed a strong taste for similar occupations. After receiving a liberal education at different public schools, he was put in command, at 18 years of age, of a merchant vessel, in which he enjoyed the

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opportunity of visiting numerous harbours, both in Great Britain and in other countries.

During the period of three years, after which Mr. Chapman left the merchant service, he lost no opportunity of making himself acquainted with the circumstances of these various harbours, and he thus acquired that valuable kind of practical knowledge on the subject of harbours, for which he was afterwards so eminently distinguished.

It is probable that no one thing has been productive of more fatal errors in harbour engineering, than the want of that extensive experience which is based upon an acquaintance with similar works, and with all the varying circumstances which affect this difficult class of operations. A harbour engineer ought, in fact, to be half a sailor, and no one can enjoy better opportunities of observing harbours, and of making himself acquainted with their merits and defects, according to the different forms of treatment to which they have been subjected, than he who navigates those very vessels for whose convenience and protection harbours are intended. One may therefore easily imagine that Chapman's nautical training was admirably calculated for an introduction to successful practice as a harbour engineer.

Mr. Chapman, guided by the natural tendency of his pursuits, sought the acquaintance of those older and better informed than himself; and even at this early age he was so fortunate as to contract a friendship with the late celebrated James Watt, with his partner Mr. Boulton, and also with Mr. Wooller, an Engineer to the Board of Ordnance. All these eminent men strongly advised him to follow as a profession that which he had closely studied as an amusement. He accordingly accompanied the late Mr. Boulton to Ireland, at the close of the year 1783, but, although well introduced in that country, he obtained no employment of consequence until after he had written a prize essay on the effects of the river Dodder on the Harbour of Dublin. Shortly after this he was appointed resident engineer to the County of Kildare Canal, a work which was carried on under the surveillance of the late Duke of Leinster, the Members for the county of Kildare, and other leading men. The manner in which the works were conducted gave so much satisfaction to the committee, that they entered on their journal a resolution expressive of their high opinion, ordering, at the same time, its publication in the principal Irish newspapers.

In the execution of this canal Mr. Chapman was requested not to alter the direction of the roads intersected by the canal, although one of them deviated from the right angle across the canal upwards of 50°. To meet this emergency, and knowing that a bridge of masonry of the ordinary construction could not possibly

stand with any considerable obliquity, he invented and put into practice the method of building oblique or skew arches, which has since that time been successfully adopted throughout the whole kingdom in the bridges of railways, roads, and canals.

Before the introduction of Mr. Chapman's method of building skew bridges, whenever a road crossed the course of a canal, river, or drain, which required the construction of a bridge, it had been usual to deviate or vary the course either of the road or the object which it crossed, so that the crossing should be at right angles. This occasioned a waste of land as well as many awkward and dangerous bends in roads which were thus treated, and was besides attended with considerable expense. In some few cases where the bridge was only required to be of small opening, no alteration in the direction was made, and a bridge was built of an oblique form, that is, with abutments forming oblique angles with the road which passes over it. When a bridge of this kind was adopted, the courses of the arch were built in lines parallel to the face of the abutments, and the ends of the voussoirs bevelled off to coincide with the direction of the road.

A bridge of this description has always one obtuse and one acute angle, and it is evident that if we conceive a plane passing through the acute angle of one abutment, and placed at right angles to the face of the abutments, such a plane will cut off a part of the arch which is obviously without support, except from the adhesion of the mortar by which the stones are held together, and from the tothing in or breaking joints of the stones with those which are fairly supported by pressure against the abutments. Such bridges, therefore, were highly dangerous when the span was great or the obliquity considerable. In other cases, where it was inconvenient to make a diversion, the acute angle of each abutment was carried out till it came opposite to the obtuse angle of the other, and the arch being completed from end to end of the abutments, the road was carried over between parapets built in the same direction as the road itself. Here, of course, there is a great waste of building, for all that part of the arch which is turned upon the extensions of the abutments, is quite unnecessary, supposing it possible to give stability to the arch without any such extension.

The value of Mr. Chapman's invention consists in this, that he gave the means of building bridges on the skew principle in any required situation without altering the direction of roads, and without any waste of material; and scarcely at any greater expense than that of an ordinary rectangular bridge.

Previous to the year 1787, Mr. Chapman had never heard of any other plan of building skew bridges than the one described above, with straight parallel courses, but about this time having the direction of the county of Kildare Canal, which is a

branch from the Grand Canal of Ireland, to the town of Naas, his attention was directed to the subject in the following manner. The directors of this canal were anxious, if possible, that the various roads should be carried over the canal without having their direction altered, and Mr. Chapman was accordingly led to inquire into the best means of effecting this. It soon occurred to him that the obliquity of some of these crossings was so great, that bridges built on the old principle with oblique angles, would be very insecure on account of the unsupported triangular part of the arch at each end. At the same time he considered, that the expense of extending the abutments so as to make the plan of the arch rectangular, would be very great, and that the work would have a clumsy appearance after all, and was therefore led to reflect upon a method of building a true and substantial arch which should have the same lozenge form of plan which the nature of the crossing determined.

In this inquiry he was soon led to detect, as a leading feature, that the courses of voussoirs, whether of brick or stone, instead of being built parallel to the face of the abutments and oblique to the face of the arch, should be made exactly the reverse, that is, at right angles to the face of the arch, in which case they will necessarily meet the abutments at oblique angles. He then saw that if the outer surface of the arch were spread out into a plane, the lines of these courses should all be straight and parallel, and that consequently when the surface was bent into its curved form, the lines would assume the same spiral form as that of a straight line wound upon a cylinder. This furnished the key for tracing on the covering boards of the centering the spiral lines of the courses, and by successive steps the original idea here indicated, was carried out with perfect success. Some of the bridges on the Kildare Canal itself were very oblique, there being one which deviated 51° from a right angle with the canal, so that the acute angle of each abutment was only the complement of this, or 39° .

The article on oblique arches in Rees's Encyclopædia, in which the particulars of the invention are described, is from the pen of Mr. Chapman himself.

During the progress of the Kildare Canal, Mr. Chapman, at the request of the Duke of Leinster, became a joint overseer with him and the Honourable Mr. Ponsonby Moore, for building a bridge of five arches over the Liffey, at New Bridge, in place of one that had been totally carried away by a flood in that rapid river. In choosing a site for this bridge Mr. Chapman could not avoid a quicksand for the foundation of one of the piers. The bridge itself was a plain structure, and there was nothing peculiar in its construction, except the means used in forming and securing its foundation, which so attracted the notice of the late Lord Perry on his road from Dublin to Limerick, that he recommended the gentlemen of that city to

apply to Mr. Chapman to survey and report on the means of effecting a communication from Loch Derg to Limerick.

From this time the number and importance of Mr. Chapman's professional employments continued to increase, and he was engaged to survey and report on the following proposed navigations, viz.: the improvement of the navigation of the river Nore from Kilkenny to below Thomas Town; the navigation of the river Barrow from Athy to near Newross, forming a navigation from Lough Erne to Ballyshannon, also from the upper Lough Erne up the Woodford River, through the small lakes, towards Leitrim, and of the whole length of the Shannon from Lough Alton; likewise the navigation of the river Avoca, and formation of a harbour at Arclow. Reports on all these projects were printed at the time, but three of them only were carried wholly or partially into execution, viz., that from Lough Erne to Ballyshannon, that from Lough Derg to Limerick, and the navigation of the river Barrow from Athy downwards. The two former of these were relinquished, in consequence of the want of funds, before the period when Mr. Chapman left Ireland, but the navigation of the Barrow was then steadily progressing and has since been completed.

During this period Mr. Chapman was appointed consulting engineer to the Grand Canal of Ireland, of which work the late Mr. Jessop was directing engineer. In consequence of this appointment, Mr. Chapman occasionally visited Ireland, and under the conjoint directions and surveys of himself and Mr. Jessop, the extension of the Grand Canal from Roberts Town to Tullamore was laid out, and also the dock between Dublin and Ringsend, and the canal of communication by the line of the circular road. The execution of this dock and of several other public works under the care of Mr. Chapman, was entrusted to the direct management of his brother, Mr. Edward Walton Chapman, who subsequently withdrew from the profession. The canal from near Tullamore passed through extensive bogs, some of which were 30 feet in depth, and in consequence of its difficulties, was laid out personally by Mr. Chapman. The directors of that canal had expended upwards of £100,000 in a very short space between Roberts Town and Bathangar, because they were unacquainted with the extent of the subsidence of bogs under superincumbent weight, or when laid dry by drainage. Mr. Chapman, therefore, took advantage of their experience, and adopted the following ingenious method of comparing different kinds of bog. He provided himself with a cylindric implement of steel plate, sharp at the lower edge, and containing precisely one hundredth part of a cubic foot, and having divided the strata of bogs into leading classes, and as many subdivisions as were necessary, he filled that implement, by turning it round to cut the fibres of the bog, with a specimen of each. As it happens that most kinds of peat earth are very nearly of

the specific gravity of water, which, in its soft state, forms the principal part of its composition, it followed that each sample thus taken and carefully cut off at the level of the top and bottom of the cylindric gauge would then weigh 10 ounces. These samples, amongst which was one from bog desiccated as far as it would be under open exposure to weather, and capable of being passed over by cattle and carriages, were all left upon a marble chimney-piece in winter, for three or four months, at which time, being in a similarly firm state and greatly contracted, they were weighed.

The originally wettest bog was found to have lost $\frac{1}{10}$ ths of its weight, and the firmest precisely $\frac{2}{3}$ rds, the rest in due progression between; it therefore became a simple process to ascertain pretty nearly the extent of subsidence in any bog to be passed through, and of course to lay out the line of the canal with such levels, that after subsidence, its surface should be at the required depth below the surface of the bog. For this purpose, when the line was laid out, Norway poles of the requisite lengths, up to 30 feet and upwards, were, at certain intervals, put down through the bog into the firm ground below, and after following a judicious process of draining devised by Mr. Jessop, and which commenced with parallel drains of small depth, at the distance of a quarter of an Irish mile on each side of the canal, in extensive bogs, the process of subsidence was found to be progressive, and in the course of little more than a year, the poles exhibited the appearance of masts of small vessels.

Amongst Mr. Chapman's other extensive employments in Ireland, he caused, at the instance of the Irish Government, a survey to be made of the harbour of Dublin to beyond the bar to Howth. On this occasion he projected a pier from the Clontarf shore, to a due distance from the lighthouse, and then to the westward to a proper distance from the north wall, so as to confine all the tidal water covering that vast space to pass down the channel of Pool Beg, in place of being permitted to flow inwards and outwards over the North Bull.

In the year 1794, Mr. Chapman returned from Ireland, and fixed his general residence at Newcastle-upon-Tyne. About this time the great project of a canal communication between the German Ocean and the Irish Sea was engaging general attention in the north of England, and the subject of this memoir was fixed upon to survey the line of country for this proposed canal between Newcastle and the Solway Firth. Mr. Chapman's reports on this subject are still extant*, and although the

- * 1. Survey of a Line of Navigation from Newcastle to the Irish Channel, by W. Chapman, 1795.
- 2. Report on the proposed Navigation between the East and West Seas, by W. Chapman, 1795.
- 3. Report on the Line of Navigation from Newcastle-upon-Tyne to the Irish Channel, 8vo, 1796.
- 4. Report on a Canal from Newcastle or North Shields towards Cumberland, by W. Chapman, 1796.

work to which they relate was never executed, the documents connected with it are so interesting that we shall avail ourselves of them to give some account of the project itself, and to throw some light upon the talents and habits of thought which distinguished Mr. Chapman and some of his contemporaries.

The report made by Mr. Chapman in January, 1795, was preliminary to the survey, and professed to be merely a report on the measures to be attended to in the survey of the canal. In this report he considers first the practicability of using the river Tyne as a part of the navigation, and comes to the conclusion that the river should not be made available above its tide way. His objections are well expressed; they go directly to the point, and will bear upon similar proposals of a later date. He says that the expense of making the river navigable would be very great, owing to its width and the nature of its bottom; that the navigation would be so frequently liable to floods as to defeat all ideas of a regular communication; that shoals would be constantly formed after great floods in consequence of the impetuosity of the torrent, which brings down gravel and large stones in great abundance; that flush weirs or any other means of keeping open the channel in dry seasons would be attended with great expense; that the river could not be thrown into a succession of still pools except at an outlay for the construction of locks which would exceed that of a canal cut through the land; and that the expense and delay of hauling against the stream must be submitted to by all the carriers of goods in the up-stream direction. For these reasons he rejects without hesitation the idea of making the river itself navigable.

He next considers the plan of pursuing the banks of the river and forming a navigation partly composed of a canal, cutting off the sudden bends of the river, and partly of the river itself. His objections to this plan are nearly as strong as to the other. He says, with great justice, it would partake of the inconveniences of making the river the chief line, and would be subject to great interruption and danger from floods. In consequence of this, the undertakers of the project must either be content to have their works occasionally overflowed, or they must, at the up-stream entrance of every part of the canal where it leaves the river, erect a guard lock, with a height equal to the full rise of the floods. The expense of every such lock with its accompanying weir, and of the raised trackway along the navigable shore, would be very

5. William Jessop and W. Chapman's Report on the proposed Line of Navigation between Newcastle and Maryport, 1795.

6. W. Chapman's Observations on Sutcliffe's Report, in 1796, on the proposed Line from Stella to Hexham, and from Hexham to Haydon Bridge, 1797.

7. Report on the Line between Carlisle and Solway Firth, by W. Chapman.

great. In addition to these objections, there are many steep projections on the verge of the Tyne which it would be difficult to cut through and protect, for which last reason alone—if there were no other—he is of opinion that the immediate border of the river is not the best line to be followed.

Then comes the question of an independent canal entirely across the dry land. With reference to the kind of canal, there are some observations on the comparative expediency of a ship canal suitable for small sea vessels, and of an ordinary canal for boats of about 50 tons burden. Considering that the ship canal would be far more expensive than the other, that there was already a ship canal* from sea to sea, and that the sea going trade of Newcastle employed much larger vessels than those for which a ship canal would be designed, Mr. Chapman thinks it advisable to confine the project to a canal suitable for boats.

With respect to the direction of the proposed canal and the position of its entrances, it will be unnecessary to follow Mr. Chapman in detail, because the arguments here are confined to local subjects, and are not capable of application under other circumstances. It may be sufficient to mention that he proposes to fix the western extremity of the canal at Maryport, which is about 23 miles below the head of the Solway Firth, and its eastern extremity at Newcastle, where he recommends the formation of a wet dock in the flat ground upon Ouseburn above the Shields Road Bridge.

The levels and direction of this canal, which was proposed by Mr. Chapman, on the north side of the Tyne, appear to have been laid out with a judicious regard to the convenience of the great mineral districts of Cumberland and Westmoreland. He had particularly in view the practicability of carrying branches through the valleys which lead up to the great lakes of Cumberland, and through the heart of those mountain districts which have become so celebrated for their slate quarries and lead mines. The principal of these branches was to be carried up the vale of the Eden, commencing a little eastward of the town of Brampton. He is of opinion that this branch may be carried to some distance beyond Kirkoswald without a lock, and that it should pass up the vale of the Emont within a very short distance of Penrith. He further adds, that if circumstances should render it necessary, there would be no impropriety in following the bed of the Emont above its junction with the Lowther; because the former river, rising out of a spacious lake, (Ulleswater,) cannot be subject to sudden or extreme fluctuations of rise and fall, on account of the mountain torrents being equalized by the slow and progressive rise and fall of the lake, and also because

* The Forth and Clyde Canal admits vessels of nearly 20 feet beam, 8 feet draught of water, and 63 feet extreme length.

the lake serves as a cesspool to collect and retain the stones and gravel that would otherwise interrupt or impede the navigation of the river. The length of this proposed branch canal from Brampton to Emont Bridge, a little west of Penrith, is about 23 miles. Lake Ulleswater itself is five miles beyond Emont Bridge, and the navigation being continued through this lake would pass for seven or eight miles in the bosom of mountains abounding with slates of the finest quality in Europe. From the carriage of these slates along the branch canal, and then along the main line, both to the east and west seas, a very large return was anticipated; as well as from the carriage of coal and other articles for the supply of Kirkoswald and Penrith. Mr. Chapman next contemplates the advantage of carrying a branch further up the valley of the Eden than where the united stream of the Emont and the Lowther falls into it. This second branch, he observes, may be carried a considerable distance without a lock, and would open up a communication with Appleby and the eastern part of Westmoreland.

Returning to the main line of canal, Mr. Chapman proposes to approach Carlisle on as high a level as possible, and to carry on this high level beyond the crossing of the Eden, in order that the town of Wigton may be brought within its course to Maryport. He observes that in coming into the vale of the river Ellen, which falls into the sea at Maryport, the canal should be kept on a level sufficiently high to admit of a branch to Cockermouth without locks. The course of the canal which is chalked out in this report is very nearly the same as that which has been adopted for the Maryport and Carlisle Railway.

The preceding observations have been confined to that part of the canal west of the great summit, which separates the Irthing from the South Tyne, the one flowing westward to Carlisle and the Solway Firth, the other flowing eastward and falling into the North Sea at Tynemouth, a few miles below Newcastle.

We now, therefore, come to that part of the canal east of the summit here spoken of, and in order to understand what follows, it will be necessary to explain that the river Tyne below Hexham is formed by the junction of two considerable rivers bearing the names of the North and South Tyne. The North Tyne is fed by innumerable mountain streams, which flow from the lead hills of Northumberland; while the South Tyne, along the northern bank of which it was proposed to carry the canal, after passing over the summit which separates it from the Irthing, takes its rise amidst a geological formation of equal importance in the county of Durham. Below Hexham the North Tyne and the South Tyne become one river, which bears the name of the Tyne for the remainder of its course.

Mr. Chapman recommends the extension of the summit level on the main canal

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as far as Hexham, and describes the facilities for carrying branches into the lead countries north and south of the line, by winding up the vale of the North Tyne, and also up that of the South Tyne, in a direction at right angles to the course of the main line where it falls into the valley of the latter river.

With respect to the locks on the main line, he observes that 14 or 15 feet would be an eligible width, but considering the steep declivities on which the canal would have to be carried throughout a great part of its course, is inclined to think it advisable to be content with 12 feet for the width of the boats. These, he observes, may draw 4 feet of water, and if made 60 or 65 feet in length, would carry about 50 tons. With respect to the branches through the lead country, he remarks that it would be extremely expensive and unnecessary to make them of sufficient size to carry boats of this magnitude. His remarks on this subject contain so much sound sense and practical wisdom that we make no apology for transcribing them.—“On the face of a mountainous country, where there are sudden bends and little soil, boats, from the first cause, ought not to be long; and from the thinness of soil and declivity of the ground, the canal would be expensive to be either wide or deep. Bridges also would be costly, not only from the expense of their erection, but the difficulty of filling their approaches on the downward side; I therefore recommend a canal of only 3 feet 6 inches depth; and at every high or by-road that there be a paved ford of 2 feet 9 inches depth, and the downward side of the ford to be an overflow, so that the water can never rise materially higher, and horses and carriages may at all times safely pass. The width and length of boats on this navigation (the branches) I would advise to be half of what they will be on the main canal; so that if found more eligible than reshipping their cargoes into the large boats, four of the small ones may proceed together, and pass through the locks with the least waste of water that the separate plans will admit of. These boats should be of the construction of the Birmingham trows, (upright sided and flat bottomed,) and when light should only draw about 6 inches water; they will then, at 32 feet length and 6 feet width, carry, according to the form of their ends, from 8 to 10 tons each, when laden to 2 feet 6 inches; and four of them, which may be navigated with one horse and four boys, will, at the lesser quantity, carry 32 tons. These boats should be connected together in pairs; each hind one, as in the Lincolnshire navigations, acting as a rudder to the fore one; in each of which, from a small mast, a light track line may go to the swingle tree of the horse.” Mr. Chapman is very particular in recommending that the chief branches should be carried from the summit level of the main canal, because in this case, as the branches are all ascending, the boats must bring with them into the main canal all the water requisite to pass them onwards, whether they proceed to the east or the

west. It is obvious that if any branch communicates with the main line only one level below the summit, all the trade of that branch, which passes the summit level, must consume two locks full of water for every boat. The plan of navigating the small boats in fleets of four together is attended with this advantage, that the four boats would jointly consume the same quantity of water in passing separately through one of their own single locks, as they would in passing through one of the large ones on the main trunk; and in ascending and descending the small locks of more than one fall, they would save both time and water by being in fleets. The remaining point of importance which Mr. Chapman considers in this report, is the expediency of confining the whole canal to dimensions suitable for the small boats, and of adopting the shallow depth of water so as to substitute fords for bridges, as explained in the quotation already made from the report. The answers to this proposal are sufficiently obvious, and need not be enumerated; it is enough to say that the small boats would be quite unsuitable for the carriage of timber and other bulky articles which would pass along the main line.

Such is Mr. Chapman's report upon the proposed line of canal between the east and west seas. He has here chalked out the leading features of a magnificent project, which even the enterprise of an additional half century has failed to realize in its full extent. It is true that we have at this day an uninterrupted line of railway from Maryport to Newcastle, embracing in its course Wigton, Carlisle, Haltwhistle, Hexham, and other places which claimed attention in the earlier project of the canal; but as yet those romantic vales, winding amidst the mountains of this rich and picturesque country, are as far off from the advantages of communication with either coast as they were in the days of Chapman. The only canal which the wide range of country embraced in his report even yet possesses, is one from Carlisle to Bowness, on the Solway Firth, a direction which Chapman rejected as ineligible for that part of this main canal west of Carlisle, his opinion, as we have already seen, being in favour of Maryport.

It appears that immediately after the date of his preliminary report, in January, 1795, Mr. Chapman received instructions to survey a line of navigation from Newcastle to Carlisle, and thence forward to such a port in the Irish Channel as should appear most eligible. The result of this survey was communicated to the subscribers in two reports made in the months of June and July in the same year (1795).

The first report is confined to that part of the line between Newcastle and Haydon Bridge. He describes the course of the canal in this district as alternately passing over deep and narrow deans by means of lofty embankments, and penetrating by excavations through the intervening rocks and mountains between the deans. In

some few cases he prefers winding round the precipitous brow of a hill to the plan of cutting or tunnelling through it. In this report, Mr. Chapman dwells at some length upon the advantage of departing from Newcastle on a high level, the principal feature in which is, that he carries the canal on a dead level all the way from Newcastle to Haydon Bridge, a distance of 31 miles, without the interruption of a single lock. On the subject of retaining the summit level of a canal for as long a distance as practicable, there are some good practical remarks in this report, which may be worth quoting. "I have already observed," says Mr. Chapman, "that the quantity of descent to be encountered from the summit to the sea must evidently be the same whatever line be pursued, but that much depends on where that descent shall be; and I have seen so many inconveniences in a variety of canals, from making that descent too soon, that I have adopted it as a maxim, never to part with height of level without fully sufficient cause. The possession of height enables various lateral branches to be made, that could not otherwise be carried into effect, without an almost insuperable ascent, and a supply of water that often cannot be acquired: it also frequently enables the further, and perhaps unthought of, continuation of a line that otherwise would never proceed, because of the necessity of a second summit, (which, where subsequent descent is requisite, requires a new supply of two lockfuls of water for every boat that passes,) and the delay necessarily occasioned by a great number of locks, which would totally cut off many advantageous sources of revenue."

In this report, Mr. Chapman contemplates the extension of the canal in the eastern part of Northumberland in a northerly direction, through the most fertile part of the county. This is a great tillage district, in which the want of lime for agricultural purposes is severely felt. Now where the line of the main canal crosses into the valley of the North Tyne, it enters the district of the great carboniferous limestone formation, and continues for about 15 miles through an inexhaustible field of limestone belonging to this formation. The carriage of this limestone to the parts of the line where it is greatly in request, is reckoned upon as a considerable source of revenue. Mr. Chapman estimates the quantity of lime required for land which is under tillage at 425 tons per square mile per annum; and he estimates the weight of agricultural produce which will be carried on the canal, at 160 tons per square mile of land; this being the amount of the produce over and above what is required for the consumption of the immediate country which surrounds the producing district. Considerable revenue is also expected from the carriage of passengers by stage-boats, and the conveyance of lead and of market produce to Newcastle, Carlisle, and other large towns on the line. Mr. Chapman announces in this report, that he had been compelled to relinquish the idea he entertained originally of extending the summit level as far east-

ward as the North Tyne, with the view of carrying branch canals up the vales of Reed and North Tyne, from both of which he expected an accession of heavy products. On trying the levels of the country, with a view to the extension of the summit level which had been at first proposed, Mr. Chapman found that the deep Vale of Caponscleugh presented a considerable obstacle, and in consequence of this and other difficulties, he gave up the prospect of carrying the summit level as far as the crossing of the North Tyne. He then turned his attention to the next great object, that of carrying the Newcastle level as far westward as possible, and it fortunately happened that Haydon Bridge, to which he proposed to extend this level, presented a very advantageous termination for concentrating the produce of the lead mines.

The second report, after the survey of the line, is descriptive of that part of the canal from Haydon Bridge to Maryport. Having investigated several passes since the date of his preliminary report, Mr. C. is still of opinion that the lowest summit between the two seas lies in the vale between the rivers Irthing and Tipple. The course of the line from Haydon Bridge to the summit level is marked by several extensive flights of locks, by means of which it acquires an elevation of 240 feet above Newcastle. The river Tipple is to be taken to supply the summit level, which is about $11\frac{1}{2}$ miles in length. The fall from the summit level to Carlisle is 374 feet, and the position of the several suites of locks by which the canal descends is particularly described in the report. The most rapid part of the descent is near a place called Gelt Bridge, where Mr. Chapman proposes a fall of 196 feet in a distance of barely one mile. He observes, that at this place the locks will be so crowded together as to require a great increase in the width of the canal to enable each lock to be filled without materially drawing down the level above it. It appears that close to this suite of locks are situate the very large and important stone quarries of Gelt. The stone is a reddish grit, and may be quarried in beds of any thickness from that of a thin flag to upwards of a foot. Besides the facilities afforded by this stone for building the locks, Mr. Chapman includes it among the most important articles of commerce on the line of the main canal.

The way of approaching Carlisle affords the next point for consideration. This city is situated on an insular piece of high ground, surrounded by marshes at the confluence of three rivers, the Eden, the Caldew, and the Pettril, a narrow isthmus across these marshes alone connecting the site of Carlisle with the high ground beyond the marshes. Mr. Chapman takes advantage of this isthmus to carry the line of canal on a low embankment up to the base of the fosse wall of the citadel. From Carlisle to Maryport, there is no important feature worthy of notice. The course is described in the report with great minuteness, and the positions particularly

pointed out of the five or six locks necessary to carry it down to the sea level. This report, like the preliminary one which has been already noticed, is not confined to the main line of canal, but embraces a comprehensive review of the various branches which may be carried off at different levels to important mineral districts, to considerable towns, and to other ports on the Irish Channel. Of these branches, the first in order and in consequence is that which has been already mentioned through the valleys of the Eden, the Emont, and the Lowther, towards Penrith, Lake Ulleswater, and the rich districts which surround this magnificent sheet of water. Mr. Chapman experiences great satisfaction in finding that the summit level of the main line can be continued up to Penrith, and that thus a branch may be advantageously opened for the conveyance of great quantities of lime, slates, coal, and the ordinary agricultural produce of the country. Between Carlisle and Maryport, facilities are pointed out for carrying branches to Ravensbank, Bowness, and Sandsfield, ports on the southern shore of the Solway Firth, but Mr. Chapman advances only very limited recommendations in favour of any of these branches.

Although these branches, in an engineering point of view, are all easy of execution, it is doubtful whether the trade to and from these ports would pay a remunerating profit when put in competition with that of Maryport, where the entrance of the main canal was to be fixed. The only other branch worthy of notice is a short one to Wigton, which town is a little more than three miles from the main canal. In concluding this report, Mr. Chapman alludes to a great leading feature in this project, which is materially connected with its future prospects to the subscribers, namely, that as it occupies all the chief passes of the country, it could never be seriously interfered with by rival canals; while, on the other hand, there is every prospect of great benefit from the promotion of inland navigations in its own neighbourhood, as these must consist of branches which will bring an accession of trade, and so add in every way to the value of the parent trunk. It is remarkable that the canal, as laid out by Chapman, between the east and west seas, although passing through one of the most mountainous districts in England, had a summit between 30 and 40 feet lower than that constructed by Brindley from the Trent to the Severn, and 50 feet lower than the summit of the Leeds and Liverpool Canal at Colne, reckoning in each case from the level of the sea.

The report on which we have been last remarking is dated the 10th of July, 1795, and it appears that, between this time and that of the preliminary report, several other engineers had been consulted on the measure. Of these, Messrs. Jessop and Whitworth had been called in by the same parties who employed Chapman, while Mr. John Sutcliffe and Mr. Dodd appear to have been opposed to the former three,

since they came forward as the advocates of a line on the south side of the Tyne. Mr. Chapman was therefore called on, at the request of some part of his own committee, to examine and report upon a southern line of canal from Haydon Bridge eastward to Newcastle, and in the following month (August, 1795) his report was delivered. It appears that the line on the south side of the Tyne is sufficiently practicable, as far as the engineering is concerned; and although the same great features of deep rugged deans and intervening mountains present themselves here as in the north line, it seems, on the whole, that the one would not be more expensive to execute than the other. In a commercial point of view the two principal advantages of the south line are the following: a great extent of coal and lead country opened up, and facilities for a branch up the vale of the Derwent, leading directly to the lead country of Durham, and capable of commanding an extensive trade in lime. In competition with these advantages, the northern line ranks in its favour a branch into the finest agricultural district of Northumberland, the command of an exclusive trade to be carried on by market boats, which, it seems, can scarcely be expected on the southern line; and in addition, a considerable trade in passage boats is exclusively claimed for the northern line. Upon the whole, Mr. Chapman sees no reason to depart from his previous views in favour of the north line, but at the same time is quite of opinion that the south line would pay as an independent undertaking for the conveyance of minerals, although he would not recommend it to be adopted as part of the main line from sea to sea. The concluding part of this report is devoted to the termination of the canal below Newcastle Bridge, the tideway down to which the canal must here descend being 205 feet below the long level of the canal from Newcastle to Haydon Bridge.

About this time, Mr. Jessop was called in to report on Mr. Chapman's proposal for a canal on the north side of the Tyne. He agrees almost entirely in Mr. Chapman's views, observing that although local deviations may be made on an accurate survey, his opinion is that no better general line can be found than that laid down by Mr. Chapman. With respect to the descent to the tideway at Newcastle, Mr. Jessop so far differs from Chapman as to recommend an entrance into the river *above* the town, instead of passing down through the town by locks, as the latter seems to have contemplated. The consultation between these two engineers on the subject of the dimensions for the boats ended in the recommendation of boats similar to those used on the Aire and Calder and other navigations in Yorkshire, namely, vessels 65 feet in length, and about 14 in breadth. Mr. Jessop's report is accompanied by an estimate for the main line of canal on the north side of the Tyne. The whole length of the canal from Maryport to Newcastle is 95 miles, and the estimate as signed by the two engineers is £355,067.

It may now be necessary to notice the views and opinions of Mr. John Sutcliffe, with reference to the best line of communication between Newcastle and Haydon Bridge. This gentleman, with Mr. Richard Dodd, appears as the earliest advocate of the line on the south side of the Tyne. We have before us two reports by Mr. Sutcliffe, the one dated 5th Oct. 1796, and the other dated 3rd Jan. 1797. The first of these is confined to that part of the navigation from Hexham to Stella, at which place he proposes to fall into the Tyne, and to use the river the rest of the way down to Newcastle. The distance from Newcastle to Stella by the river is about five miles, and from Stella to Hexham about 17 miles. Mr. Sutcliffe begins by showing that a good line of canal navigation may be made between the two latter places, and severely animadverts on Mr. Chapman's recommendation, in case a south line should be adopted, to form a navigable canal only between Stella and Stanley Burn, about one third of the distance to Hexham, and to make the river navigable from Stanley Burn upwards towards Hexham.

Mr. Sutcliffe deals out a censure no less severe upon the line originally recommended by Mr. Dodd on the south of the Tyne, remarking on the two projects: "I have examined this proposed cut," (from Stella to Stanley Burn,) "and the river from Stanley Burn to Bywell, and I am of opinion that, however improper the line might be that was first surveyed," (alluding to Mr. Dodd's line,) "still I think the idea of making the river Tyne navigable between the two above mentioned places more absurd." Mr. Sutcliffe continues: "I have not the pleasure of knowing Mr. Chapman, nor can I form so mean an opinion of his understanding, as to believe him serious when he recommended, or rather pointed out, the plan of making the river navigable. I consider it intended only to amuse the mine and land-owners on the south of the Tyne, while his friends obtain an Act for a canal on the north side of the river."

Mr. Sutcliffe declares that, so far from a canal being impracticable all the way between Hexham and Stella, an exceedingly good and useful canal may be made between the two places; and that there is no piece of work on the line that will be attended with any uncommon difficulty or with any uncommon expense in the execution.

After describing particularly the course of the line, Mr. Sutcliffe has some valuable remarks on canals generally, which will throw some light upon the extraordinary zeal with which canal speculations were entered upon in his day. The large interest paid by some of the principal railways in this country has probably far exceeded the expectations of the more sober-minded thinkers who looked forward with doubt and mistrust to the results of the lavish expenditure which has accompanied these works. The most profitable railways, however, have never realized any thing like the same interest as some of the canals here quoted by Mr. Sutcliffe.

In the year 1792, for instance, the Aire and Calder navigation paid the original subscribers something more than 100 per cent. clear profit; the Dun navigation paid about 80 per cent. clear profit to the original subscribers; the Erewash Canal, in Derbyshire, paid about 35 per cent. to the original subscribers; the Sankey Canal, in Lancashire, paid near 30 per cent. to the first subscribers; the Birmingham Canal paid to the first subscribers upwards of 70 per cent., although this is but a short line, the summit level being only about 14 miles, and subject to the great disadvantage of lifting nearly all its supply of water a considerable height by steam-engine power^a.

Mr. Sutcliffe places in a prominent point of view the advantages of the south line to the important collieries of the Duke of Northumberland, which lie principally on this side of the river, and alludes to the valuable results which will follow the conveyance of the limestone, which is very abundant in the neighbourhood of Hexham, into the country adjacent to the Derwent. "This line," he says, "will be extensively applied to the improvement of waste tracts of land, which must otherwise long remain in a very unprofitable state."

It should be observed that, although Mr. Chapman and Mr. Sutcliffe agree so far in their views as to propose the navigation of the open river between Newcastle and Stella, they differ widely as to the mode of carrying on the trade beyond Stella; Mr. Chapman being of opinion that the canal boats would be unfit for navigating the river, and, consequently, asserting that all cargoes must be transhipped at Stella. Mr. Sutcliffe, on the other hand, maintains that the same boats may go all through, and strenuously combats Mr. Chapman's statement in the following terms. "Is it from ignorance, prejudice, or a disregard to truth," he asks, "that so much pains are taken to persuade the public that the vessels which are to navigate on the south canal cannot navigate on the river or in the tideway? Does not Mr. Chapman, the engineer for the north line, know that the same vessels that navigate 33 miles on the Duke of Bridgewater's canal, descend at Runcorn by 144 feet of lockage into a rapid river, where the tide rises to a very great height at the tail of those locks? The distance between Runcorn and Liverpool being about 11 miles, and the river Mersey below those locks, as much exceeding the Tyne at Newcastle as the Tyne exceeds some of the brooks that feed it. Is Mr. Chapman ignorant that the same vessels that go from Halifax, Huddersfield, Wakefield, and Leeds, navigate upon those rapid rivers the Calder and Aire; and when they arrive at Selby, fall into the tideway, and navigate in it more than 20 miles before they arrive at the port of Hull, (and some of these vessels proceed forward to the London market,) though the tide between

^a See Life of Brindley, p. 34.

Selby and Hull rises higher than at Newcastle? Has he never been informed that vessels are built to navigate on the Barnsley Canal, the Dearne and Dove Canal, the Malton Canal, the Driffeld Canal, and that all these vessels navigate a great length in the tideway before they arrive at Hull, and never unload their cargoes until they arrive at this port?

“When the Kennet and Avon Canal is finished, it will open a communication between the cities of Bristol and London, and there are six or seven miles in the tideway at the Bristol end, and near twice that distance in the Thames. The distance or length of the river navigation between Bristol and Bath, is 15 miles, and the length of canal from Bath to Newbury, is 60 miles; and then the boats or vessels will lock down into the river Kennet and pass 20 miles upon it to Reading, and then drop into the Thames, and so proceed forward to London.

“The distance from Reading to London, by the river, is 80 miles, and it is a well known fact, that the floods in that river are as great, and continue much longer than in any river in this kingdom; but notwithstanding this, the vessels will go from Bristol to London with 40 and even 50 tons’ burden, without unloading. As vessels navigate on the before mentioned canals and rivers, and proceed forward in the tideway without unloading, I can see no reason why the vessels that are to navigate on the south canal cannot proceed to Newcastle or even to Shields in the same manner; and what the insurmountable difficulties are that Mr. Chapman has discovered in the Tyne that forbids this, I freely confess I am not able to find out.”

This is certainly a strong array of examples, and we cannot doubt that they produced the effect of convincing many persons interested in the project that the navigation could be carried on by boats passing to and from the river into the canal, as Mr. Sutcliffe proposes. The remainder of Mr. Sutcliffe’s report is principally directed to show that the charge for tonnage on the south line would be much lower than that on the north; and he concludes with some remarks on the cost of his own line. It appears that Mr. Chapman and Mr. Jessop calculated the expense of the south line at £69,081, but Mr. Sutcliffe boldly ridicules the idea of being able to make it for any such sum, and declares that his own estimate amounts to nearly £90,000. We are inclined to think that in this instance at least, he was nearer to the truth than his opponents; and at all events, one cannot help admiring the candour with which he acknowledges this large excess, which must have added considerably to the difficulty of going forward with his own line.

The following remark on the prices which he has allowed, will show the value of earthwork in those days as compared with the present time: “I have allowed,” he says, “for digging the canal on favourable ground, 6*d.* per cubic yard; puddling,

6*d.* per superficial yard; for the embankments, 7*d.*, and for the deep digging in Farnley Scar and other places, 1*s.* per yard; and the same liberal prices are allowed for all other parts of the work." This report is accompanied by a detailed estimate.

Mr. Sutcliffe's second report is directed to an examination of the south line of canal, between Hexham and Haydon Bridge, and to a general comparison of the north line with the south. The first part of the report is principally taken up with a comparison of the circumstances under which the north and south canals could be supplied with water. He asserts, that as the north canal will derive its chief supply at Haydon Bridge, the packet-boats, which are calculated to sail swiftly, would severely feel the distressing effects of navigating up to Haydon Bridge against the current. He goes on to argue the impracticability of obtaining water for the north line by means of reservoirs, as proposed by Mr. Jessop, and paints in favourable colours, the superior advantages of the south line in this respect. Of course it will be impossible for a reader, without some personal knowledge of the country, to decide upon the accuracy of the rival engineers in a matter of this kind, we shall therefore omit any further notice of the dispute relating to the supply of water.

He next attacks the estimate made by Messrs. Jessop and Chapman, condemning the amount at which they have calculated the south line, as equally insufficient with the estimate made for their own line. He observes, that they have estimated the building of the locks at £65 8*s.* 4*d.* per foot rise, and then adds the following information as to the cost of locks on other canals. "The locks of the Ashton Canal, near Manchester, are built of brick, the canal is narrow, and the building of them was let for £75 per foot rise; but this sum was found insufficient to complete them in a proper manner. The locks on the Leeds and Liverpool Canal, near the summit, are very good ones, and have cost about £120 per foot." He then personally attacks Mr. Jessop in a very bitter and sarcastic strain, alluding to the failure of some of his aqueducts, and of a tunnel in Gloucestershire, and begging to be informed whether he intends to build locks for this canal which shall share the same fate as these works.

He comes next to the consideration of revenue to be expected from the north line, and argues upon the several anticipated sources, as lime, coal, grain, &c., that none of these articles can be expected in any thing like the same quantity as on the south line, nor in sufficient abundance to pay a reasonable return.

Returning to the estimate made by Messrs. Chapman and Jessop for the north line, the aqueduct over the North Tyne now arrests his attention. "The height, from the top of the battlement to the foundation of this aqueduct, will be near 80 feet, and the breadth of the river where it is proposed to be made, is about 270 feet." He asserts that his opponents have not included this work in their estimates at all, and he himself

calculates its cost at no less than £20,000. On the subject of aqueducts, he refers to the one then being built by Mr. Rennie over the river Lune, near Lancaster. This great work consists of five arches, each 70 feet span; the height from surface of water in river to that of water in canal is about 50 feet; and the piers are 18 feet under water. Mr. Rennie's estimate for that aqueduct was about £25,000, and 12 months ago, the Committee informed the subscribers by a printed paper, that they had paid upwards of £25,000 on account of the aqueduct; and at that time "I believe," says Mr. Sutcliffe, "there was not one arch turned."

The remainder of the report is occupied with some very sensible observations on the evils and bad consequences of hasty and insufficient estimates. He accompanies this report with comparative estimates of the north and south lines between Newcastle and Haydon Bridge, by which he makes a difference of £21,391 in favour of the south line. These reports of Mr. Sutcliffe are cleverly written, and display much ingenuity and considerable knowledge of his profession; which latter appears most obvious in the detailed estimates he has given. They are deficient, however, in that sound and practical wisdom which characterizes those of Chapman, and must be decidedly condemned for the strong inclination which he exhibits to indulge in sarcasm and ridicule at the expense of his opponents.

Chapman's reports of this date are evidently the production of a man who knew and felt his position. He makes assertions and statements on the most important subjects, and suffers them to rest upon, and derive their support and value from, his own personal credit and professional character. His statements are therefore less copiously supported by illustrations and references to other works and to other known examples. Sutcliffe, on the other hand, anxious to produce full conviction, and fearing to leave any thing unsupported, loads his reports with analogous cases and statistical facts, collected and brought together to bear upon the subject he is discussing.

The subscribers to the north canal deposited their plans in November, 1796, and prepared to go to Parliament in the ensuing Session, with that part of their line between Newcastle and Haydon Bridge. In the mean time they called upon Mr. Whitworth to report his opinion of the north line, and this engineer, after going over the line and minutely examining the principal points, sent in his report to the Committee in February, 1797.

There is evidently a great deal of straightforward candour and honesty in this report of Mr. Whitworth. Although specially employed by the promoters of the north line, he does not hesitate to differ from Mr. Chapman on several important points, particularly as to the expense of the aqueduct over the North Tyne, and one or two other difficult works on the line. With respect to the aqueduct, Mr. Whit-

worth is of opinion that Mr. Chapman's estimate of £10,500 is too low, that Mr. Sutcliffe's estimate of £23,500 is too high, and thinks that about £17,000 will be something like the cost of this work. At the time of Mr. Whitworth's report, it seems to have been decided by the Committee, that the communication between the river Tyne and the head of the canal at Newcastle should be made, not by means of locks, but by a self-acting inclined plane. Mr. Whitworth highly approves of the plane, and as the report before us contains certainly one of the earliest descriptions of this highly important method of working which has since been so extensively adopted in the mineral districts, it may be interesting to extract Mr. Whitworth's description. "The place proposed for the inclined plane is a very convenient one: it being about 400 yards long, and the fall 200 feet, which is just 6 inches in a yard; nearly the same as that I proposed in the Durham Canal. This may be made a complete and useful machine to convey the coals from the boats upon the canal to the keels in the river, if it be made and wrought in the manner I have described in my report of the Durham Canal. But as that report may not be in many hands, I will describe it here. This inclined plane must be double, at the upper and lower ends of which there must be a strong wheel fixed with the same inclination as the inclined plane. These wheels I would propose to be about eight feet diameter; and the middle of each of the inclined planes to be just the distance of the diameter of the wheel. This inclined plane will form an angle with the horizon of nearly 9° , which I suppose is a declivity fully sufficient for the loaded waggons going down to bring the empty ones up. To connect these two wheels there must be an eight or nine inch endless rope to go round them, with loops upon it at convenient distances, suppose twenty yards, to hook on the loaded waggons going down; and the empty ones at the bottom to be hooked to the loops upon the ascending side of the rope.

"The waggon must be run upon a level platform upon the boat, which may be made of any length to hold a sufficient number of them, perhaps 15 or 20; but I suppose it will be found convenient to have them smaller than the waggons commonly used; they will be more manageable. They may be conveyed to the head of the inclined plane, and there taken off the platform one by one, and hooked to the loops of the endless rope, and sent down the inclined plane, where there will be persons at the bottom to take them off and convey them to their respective staiths, which of course will be erected along the wharf at the foot of the inclined plane, and then discharge them into the keels that will be ready to receive them; the empty waggon to be brought back and hooked to the first loop that presents itself on the ascending side of the rope. It will be necessary to have a brake at top and bottom to stop the mo-

tion while the waggons are unhooking or hooking on again, but this need not stop the machine half a minute.

“It will be necessary to fix as large rollers as will permit the waggons to pass over them in the middle of both the descending and ascending inclined plane, to bear up the rope from trailing on the ground when there is not a sufficient number of waggons to bear it up; but this will not often happen.

“The upper wheel must be fixed upon the upper side of the canal, that it may not obstruct the loaded waggons passing from the platform upon the boat to the wharf at the end of the inclined plane; and, on the contrary, the empty waggons from the wharf to the platform.

“It will be necessary to have a cog-wheel, upon the axis of the upper wheel, which would be best of iron seven or eight feet diameter, with a pinion or rather two pinions of different powers to work upon it, to be worked by one or two men occasionally, to give motion to the machine when the empty waggons (or perhaps now and then a loaded one coming up) are an overmatch for the loaded ones going down, which may sometimes be the case; but when the loaded ones going down are too powerful, (which will happen when there is only an equal number of empty ones to counter-balance them,) then the brake must be the regulator, which, with a very little care, may be managed to the greatest nicety to go at what speed is thought proper.

“This iron cog-wheel will likewise be necessary to bring the loaded waggons upon the boat to the head of the inclined plane. For when the boat comes up loaded with a number of waggons, the platform may be a foot or more below the wharf at the head of the inclined plane; therefore it will require some power to bring the waggon up, which the wheel and pinion will easily do, by keeping the boat at a proper distance from the wharf, (for which purpose the canal should be 50 feet wide at this place,) and fixing a loose piece of railway, which must be provided and kept for that purpose, to the wharf and to the platform upon the boat; on the contrary, when the boat is nearly unloaded, the platform may be considerably above the wharf; in that case the brake only need be made use of to regulate the motion, that it be not too quick.

“This machine being completed in the manner described above, it will be capable of conveying a great quantity of coal, lead, &c., from the canal to the river, which I expect will, perhaps, be ten times more than will come from the river to the canal by the inclined plane. I know not what quantity of coals, lead, &c., will come to the head of this inclined plane; but I think it very practicable, if the men be moderate handy about their business, to send between 20 and 30 loaded waggons down every hour, nay I think it possible to send near 50, and as much merchandize, such as timber, &c., up as wants to come, without the assistance of a fire engine.”

Mr. Whitworth's report certainly cannot be construed into any thing like an approval of the north line ; and being shortly after called in by the promoters of the south line to report upon their project, he declared that although there were bad places on the south, it still had very much the advantage, both in point of tonnage and expense. From this time, therefore, Mr. Whitworth ranks as an opponent of the north line, himself and Mr. Sutcliffe henceforth opposing Mr. Chapman and Mr. Jessop in their attempts to carry the north line through Parliament.

At the time of Mr. Whitworth's report, the bill for the north line from Newcastle to Haydon Bridge was already before Parliament, and was naturally causing great interest, and rousing many conflicting opinions in a country where projects of this kind had hitherto been quite unknown. Numerous petitions were presented for and against the bill. Amongst the former we find one from the Commissioners and Governors of Greenwich Hospital, who were extensive proprietors of land through which the canal would pass, and also of valuable lead mines in Alston Moor ; another from the owners and occupiers of land on the line ; and a third from the burgesses and inhabitants of Newcastle-upon-Tyne. The principal petitions against the bill were those of certain other land-owners, and that of the minister and inhabitants of the parish of St. John Lee, who were apprehensive that the canal, which it was proposed to carry on the side of a hill below the church, would endanger the safety of that edifice.

A violent Parliamentary contest appears to have followed between the promoters of the rival lines, but few particulars relating to it have been preserved, except a publication of Mr. Sutcliffe's evidence, with comments upon it by the promoters of the north line. As this evidence relates principally to points of local interest in the comparison of the two lines, and as we are not in possession of the evidence given on the other side, it may be unnecessary to notice this part of the subject more particularly. Whatever may have been Mr. Sutcliffe's professional character and standing, particulars respecting which we have no means of judging, except from the reports and evidence before us, it is quite certain that he possessed and exercised sufficient talent and address to damage most seriously the project for connecting the two seas by a north line of canal. At all events, the opposition raised against the north side canal from Newcastle to Haydon Bridge was so powerful as to cause the withdrawal of the bill, "not," say the promoters, in a pamphlet which they published at the time,—“not from the *impracticability* of the proposed line, or from its being ineligible, but from the various incidental causes generally attendant on public measures, which at a future period may be obviated, by removing the prepossessions that had, on slender foundations, gone forth against it.”

The bill here referred to was before Parliament in the year 1797, after which time the project of a communication across the island lay dormant for many years. Mr. Sutcliffe's proposal for a south line never went the length of appearing before Parliament, but in 1808 the project of a canal from the Solway Firth to the German Ocean was revived, and Mr. Telford was employed to survey and report upon the best line of canal between Carlisle, and a suitable port on the Solway Firth or the Irish sea, with a view to the future extension of such a canal across the island. Mr. Telford finding that coasting vessels could navigate the Solway Firth up to Bowness, a port about 13 miles below Carlisle, recommended a canal for small sea going vessels between Carlisle and Bowness. Although Mr. Telford's plan was highly approved, the time had not even then arrived for carrying out even this small portion of the original great project; and it was not until 1818, when Mr. Chapman drew out a plan and report upon this line from Carlisle to Bowness, that a bill was brought into Parliament, upon which an Act was obtained early in 1819. This canal, which has now been in successful operation for many years, is $11\frac{1}{2}$ miles in length, and has cost about £120,000. It commences on the south-eastern side of Carlisle, and falls into the sea through a height of 70 feet by means of nine locks. Commencing at Carlisle, where there is a convenient basin, the first reach is four miles in length. It then falls 46 feet, by six locks, in the next mile and a quarter. Thence to Fisher's Cross, near Bowness, the canal is level, and it then falls 24 feet into the sea by three locks, each of eight feet lift, with basins between them, called the upper and lower Solway Basins. The lower of these basins is on a level with the high water of lowest neaps, and the other is on a level of 15 feet 6 inches higher, being the level of an extraordinary high tide which rose to this height in January, 1796. Mr. Chapman proposed eight feet depth of water for this canal, with locks 74 feet long and 17 feet wide.

There is a reservoir in the parishes of Grinsdale and Kirkandrews upon Eden, on the south side of the canal, for supplying it with water. A supply for the summit level is also pumped up from the river Eden, and about two years since the Company erected a very powerful pumping engine, which was constructed for them on the Cornish principle by Messrs. Harvey and Co., of the Hayle Foundry.

About the year 1796, Mr. Chapman became a Member of the Society of Civil Engineers in London, which, at that time, consisted of the late Mr. Watt, Mr. Jessop, and Mr. Rennie, and numbered amongst its honorary associates many members of both houses of the legislature, also the late Sir Joseph Banks, and other literary men. In conjunction with Mr. Rennie, he was then occupied in devising the London Docks, and subsequently the southern dock and basin at Hull. He was also engineer

to the Commissioners of Leith Harbour and Scarborough Harbour, and constructed the Seaham Harbour for the Marquess of Londonderry. His employments up to the time of his decease, in drainages, canals, and harbours, and in reporting upon numerous public works in all the branches of his profession, in various and distant parts of England and Scotland, have been so extensive and well known as not to require further enumeration.

In addition to his regular professional occupations, Mr. Chapman devoted a portion of his time to publications on subjects bearing on engineering. Amongst these were the following:—A treatise^a, in 4to, with plates, on the various inventions, at different periods, for effecting ascents in rivers and navigation, published at the Architectural Library in High Holborn. Hints on the Necessity of Legislative Measures for registering the extent of Workings in the Coal Seams, and preventing such accidents as arise from want of that knowledge. An Essay on Cordage^b. A Treatise^c on the Preservation of Timber from Premature Decay, dedicated, by permission, to the Lords of the Admiralty, and also containing an economic method of preserving the timber of ships already built. A striking instance of the efficacy of the plan recommended for the latter purpose has occurred in a steam dredging-vessel of 100 tons, built at Shoreham in 1818, which, although frequently closed up for many months, and when in use exposed to the moisture of steam from the boiler, is reported to be perfectly sound.

In his treatise on the various systems of canal navigation, which is dedicated to the Duke of Bridgewater, Mr. Chapman considers a great variety of expedients which had been proposed at different times to facilitate the passage of boats upon canals from one level to another. The system of narrow canals to be worked by inclined planes intercepting the different levels, as proposed by Mr. Leach, Dr. Anderson, and Mr. Fulton, was at that time very prominently under the notice of the public, and Mr. Chapman fairly discusses the merits of the plans brought forward by these gentlemen and others, in opposition to the system of forming wide canals with locks for passing from one level to another. It would be an unnecessary waste of time to occupy these pages with any particular notice of the arguments in favour of the inclined planes and the narrow boats with wheels, which Mr. Fulton proposed and

^a Treatise on the various Systems of Canal Navigation, in 4to, with several plates, 1797.

^b A Treatise on the progressive Endeavours to improve the Manufacture and Duration of Cordage; with a discussion on the means of causing ships to ride at anchor with greater safety, by W. Chapman, Esq., M.R.I.A., Member of the Soc. of Civil Engineers of London, 1808, in 4to, with three engravings.

^c Published at the Architectural Library, 1817.

others recommended, because the question of comparison has long since been settled by universal consent in favour of the highly ingenious expedient of locks.

Although our author, with reference to inland navigation generally, is decidedly in favour of canals with lockage, he discusses the subject with great fairness and candour. One chapter is devoted to a description of the great canals of the Chinese, who, it is well known, are strangers to the comparatively modern contrivance of the lock, and who at this day adopt inclined planes, where several hundred men are employed at the same time in dragging up their boats. Of course so lavish an expenditure of labour would be out of the question in any other country except China, where human power is by far the cheapest that can be applied.

Mr. Chapman takes a masterly and comprehensive view of the hydrography of North America at that time, and thinks that Fulton's system might be found very useful in facilitating the navigation of the great rivers and lakes of that country. He is further of opinion that the narrow canals, inclined planes, and wheeled boats of four feet, or a little more, in width, as recommended by Fulton, might be employed with advantage in mineral districts where there is a scarcity of water for lockage, where the falls are considerable, and where the still water levels of the canal can be laid out in long reaches, and so as to concentrate the acclivities into short lengths and few places.

Besides the above arduous employment for his leisure hours, Mr. Chapman occupied himself with the invention of several mechanical improvements. The first was undertaken before he went to Ireland, in consequence of a programme sent to different countries from the Batavian Society of Experimental Philosophy in Rotterdam, requiring a description of the means of enabling a fixed and uniform motive power employed in the raising of water to regulate its action, so as always to work at its maximum, under any varying column of water to be raised. For the solution of this problem they proposed a gold medal as the first prize, and three successive silver medals to the various candidates, according to their respective merits; engaging at the same time to publish the Prize Essays in the annals of the Society; which last circumstance was the chief motive with Mr. Chapman. He was awarded the first silver medal, but being advised by that eminent philosopher, Mr. Watt, to desire a copy of the Prize Essay, he reviewed and refuted it, requesting the Batavian Society to publish the refutation also in their annals. The Society virtually admitted the validity of the refutation, as not one of the Essays was published by them.

The late Mr. Balfour invented a method of making the strand of ropes with yarns of different lengths, and accordant with the length of their different spirals, and

dependent on their distance from the centre of the strand. This invention, so far as it went, was highly meritorious; but it had not been taken into contemplation that when a rope became stretched, its diameter was consequently contracted, and the outward yarns became slack.

In the same year, the late Captain Huddart, of scientific memory, invented a perfect principle, that of further twisting the strands formed by Balfour's method so far as to tighten the outer yarns and cause the whole to wear equally when strained. Both these gentlemen obtained His Majesty's exclusive patent for their inventions and constructed works to carry them into effect. The first described was expensive and defective, and was consequently soon laid aside. Captain Huddart constructed his works at Maryport, and succeeded to the utmost in producing increased strength in his cordage*. The method of Captain Huddart was, however, so tedious and expensive, that his establishment at Maryport began to decay, and Mr. Chapman then applied himself to invent simpler and easier methods, in which he succeeded to such an extent as to justify him in obtaining a patent, in which he included every practicable plan, whether in an extended rope ground or in a building where the strands and ropes were coiled up as they were made. This method was successfully carried into effect in all the rope grounds on the river Tyne, and in some of those on the Wear and Tweed, but from the difficulty of sustaining a patent right under the disposition of the old law, Mr. Chapman did not derive that advantage to which his invention fairly entitled him.

Mr. Chapman's next invention, for which he also obtained a patent, was for an expeditious and easily practicable method of lowering coal waggons with their contents immediately over the hatchways of ships, so as to prevent the great breakage of coals which attended the usual method of shooting the coals through long spouts. During the existence of this patent, the validity of which was not disputed, no coal company adopted the plan but the owners of Ouston colliery. No sooner, however, had the term of the patent expired than the system became universal on the Tyne, greatly to the benefit of those who used it, but without any emolument or acknowledgment to the patentee.

He also obtained a patent for a method of transferring coals from keels to the ships, by the intervention of a small vessel between them containing a steam engine and necessary machinery; this plan, embracing some very ingenious arrangements,

* For a very elaborate and descriptive article, with very amply illustrated engravings of the machinery employed in Deptford Dockyard, for spinning hemp and manufacturing ropes and cables, principally on Captain Huddart's plan, see a Paper by Mr. John Miers, F.L.S., in Vol. V. of the "Papers of the Royal Engineers," 4to, 1842.

was adopted by the Marquess of Londonderry, and fully answered the purpose for which it was intended, and continued in use until the completion of Seaham Harbour^a rendered it no longer necessary. Other patents have been obtained by him separately, or conjointly with Mr. Edward Walton Chapman, which, although containing very ingenious combinations of machinery, have not been carried into effect^b. Mr. Chapman also invented a method of loading coals from the keels into ships by stationary machinery of a simplified and safe principle, which superseded the necessity of engaging and disengaging machinery in the different parts of the process. On the Monkwearmouth shore of the river Wear, below the bridge, Mr. Chapman constructed two machines on this principle, each of which is capable of loading a hundred tons in an hour. He also invented a machine for composing a rope of indeterminate length from twelve inches downwards, upon the principle of Mr. Huddart. A machine on this principle was constructed by Mr. Chapman at Willington Ropery on the river Tyne, and is now in daily use.

Mr. Chapman, possessing a robust constitution, and practising through life the most temperate habits, retained the full enjoyment of his faculties, and followed the active pursuits of his profession till within a very short period of his decease, which took place on the 29th of May, 1832, having then entered into his 83rd year. Gifted with a strong understanding, and with great and acknowledged talents, Mr. Chapman was equally distinguished in private life by those amiable qualities which adorn the domestic scene and constitute its chief enjoyments. It may be truly said, that few men have descended into the grave more sincerely lamented by immediate relatives and connexions, or more generally and extensively esteemed and respected.

^a Description of the Port of Seaham, in explanation of the Plan of the Harbour, and a Chart of the Coast, in quarto, with a Plate, by William Chapman, 1830.

^b Specification of a patent granted to William Chapman, of Merton House, in the county of Durham, Civil Engineer, and Edward Walton Chapman, of Willington Ropery, in the parish of Wallsend, in the county of Northumberland, Rope Makers, Dec. 30th, 1812, for their invention of "A Method or Methods of facilitating the Means and reducing the Expense of Carriage on Railways and other Roads." Small 8vo, with two folding plates, Newcastle-upon-Tyne, 1813.

THE DREDGING MACHINE.

THE importance of the dredging machine in hydraulic engineering has excited much controversy as to whom the invention is due ; and we confess that our attention was seriously called to the subject by the startling and determined tone assumed by Mr. Blunt, when speaking of the dredging apparatus, in a recent division of his work, and it is but justice to state that we were prepared, certainly, for Mr. Blunt's account of the late Mr. Rennie's dredging apparatus wearing the impress of a partial leaning in favour of that gentleman's claims, as the inventor and originator of this machine ; and this conclusion was drawn from the circumstance of his long connexion with the present firm of the Rennies as their assistant. The truth of Mr. Blunt's account, however, is borne out by the following data and facts, from which this paper has been drawn up, and which have been specially furnished, completely setting the matter at rest, and confirming in every particular the undoubted claims of the late Mr. Rennie, as explained by Mr. Blunt in the division of his work above referred to. Like other ingenious contrivances, it has had its progresses and its improvements, until it can scarcely be recognised as the same simple instrument which performed the same operation as it now does in its mature state.

The process of lowering a shoal by dragging over it a board or rake, or a roller armed with spikes, or of removing it entirely by means of spoons, would naturally suggest a series of spoons, or boards, or buckets, and the difficulty of working them by the power of men when connected together, would of course suggest the employment of animal power, and finally the steam engine.

But as the history of these improvements is obscure, we shall, in justice to those whose names have been connected with the invention, endeavour to trace its different steps.

ENG. III.

B

The earliest notice we have of the primitive dredging machine is contained in a curious and rare work by Verantius, dated 1591, in which plate 41 represents two pontoons lashed parallel to each other, but at a sufficient distance to allow of the working of two dredging spoons between them, in opposite directions, and by means of a walking wheel. The material thus raised is allowed to fall into Hopper barges, as at present.

In 1618, Savory took out a patent for a steam-engine for raising ballast or gravel out of our rivers, and for lifting water.

The next notice is to be found in a work published by Cornelius Meyer, a Dutch engineer, entitled "L'Arte di restituire a Roma la tralasciata Navigazione del suo Tevere."—Roma, 1685. Part second.

This machine differs very little from the modern dredging machine, with the exception that there are boards for raising the soil through a trough, instead of buckets, and that horses are used instead of steam.

The author states, that similar machines were then in use in Holland for clearing out harbours and canals, and that they raise twenty barges a day of sand*. A description of a spoon-dredging machine is given by Mortier, a Dutch engineer, in 1734^b.

In the *Theatrum Machinarum* of Leupold, dated 1774, we have the plan and description of a dredging machine, by Hertel, and which was tried at Amsterdam in the year 1708, under the name of *mudder mole*, or mud machine.

The dredging machine of Balme consisted of a vertical wheel placed in the middle of a pontoon, with six buckets attached to its circumference, and which could be raised or lowered by means of screws^c.

The scoop-wheels of Redelykheid in 1774, and of Ekhardt in 1780, were said to answer well, but were only adapted for working in shallow water^d.

The spoon-machines described by Belidor in his *Architecture Hydraulique*, were

* Quando se volesse far operare con più prestezza, e più vigore, sarrebbe necessario de provedersi d'un pontone, o cava fango, conforme usano in Olanda per nettare i porti, i canali, e cavano con questo dal fondo in un giorno ben trenta. Barche d'Arene l'Ordegno che si manda sotto acqua è fatto a foggia d'un cassone piano con alcune Catene, ò Scacchi, che tagliano il fondó, e portano l'arene nel medesimo Cassone, che doppio ripieno viene tirato ad alto per via delle ruote dell detto Cavafango, che si voltano per opera d'una cavallo, che si mette nel Casino del detto Pontone.

^b Groot Volkomen Molen Boek. 1734, Amsterdam.

^c Ponton pour curer les ports inventé par M. De la Balme, *Machines Approuvées* par l'Académie, 1718. This is the first machine in which buckets were employed.

^d De Nieuw Uitgevonden Diep Machine door Corneli Redelykheid, Amsterdam, 1774, and described by Brunnings in 1773.

simply spoons worked by tread-wheels, similar to the machines still employed at Toulon, Brest, Venice and Genoa. The dredging machine, or Machine à Hotte, described by M. Lonce, had four buckets*, and similar machines were employed for taking out the foundations of the bridges of Moulins and Orleans by Perronet, and at Dieppe by De Cessart.

The introduction of Dutch engineers into the Great Bedford Level, in the reign of Charles the First, in all probability led to the first application of the dredging machine in England.

In a rare little work, belonging to R. P. Cruden, Esq., of Gravesend, entitled "An Account of several new Inventions and Improvements," &c., dated London, 1691, by T. S., or Thomas Hull, there is the following letter.

LETTER TO THE EARL OF MARLBOROUGH.

"MY LORD,

London, 1691.

"There is another incomparable invention that was found out not many years since, and it is the new engine that so much exceeds all formerly used for the eternal preservation of our royal rivers, by deepening them and making them everywhere navigable, and taking away all obstructions and shelves in a very short time. Sir Martin Beckman, the chief engineer of England, and, as I am informed, the ingenious Sir Christopher Wren, have given their approbation thereof, as likewise did king Charles the Second, who was highly pleased therewith, and declared after he had seen the working of the engine, which in his majesty's presence took up about a ton and a half in little more than a minute's time, that he was perfectly satisfied it would answer the end proposed; and that by means of its working horizontally, it made no holes, but rather filled such as lay in the way of its working, and left the bottom of the river level as it wrought, whereby such inconveniences would be avoided as had happened from the common ballast-lighters making such great holes, that in the river Thames, and in which several of the king's, as well as merchants' ships, coming to an anchor had broke their backs.

"And his majesty having been made acquainted that this engine, being sent down below bridge to Berking Shelf, where is nothing but hard shingle, and that after an hour's breaking ground it took up, at nineteen feet deep, about two tons in a minute and a half, during the whole time it wrought, he said thereupon, 'that he thought there was no way practical for deepening the river of Thames and removing shelves therein but by this engine.'

* Machines Approuvées par l'Académie, No. 491, 1753.

“ This engine was invented by Mr. Bayly, an excellent engineer, and much cultivated and improved to its perfection by the great expense of Mr. Joseph Collinge.”

In the year 1768, Mr. John Golborn, of Chester, an engineer of eminence, formed a scheme for the improvement of the Clyde, by means of dredging away the shoals and contracting the channel of the river to preserve the depths ; the estimate was £9000, but before he completed his improvements in a length of fourteen miles, the works cost four times that sum.

The machine employed for that purpose consisted of a wooden rectangular frame, with a slanting plank or scoop of cast iron, or wood sheathed with iron, which projected under the bottom, and was capable of being adjusted to any angle suitable to the nature of the materials ; the machine was dragged backwards and forwards, across the river by capstans fixed to the shore, and the materials served to make good the banks on either side. A similar machine, but with the addition of a harrow to loosen the hard materials, was proposed, and we believe used, by a Mr. Edington in the Thames in 1804.

In the year 1785, Mr. Grundy, engineer to the Hull dock, caused a dredging machine to be constructed for clearing out the mud from the docks. This machine was in every respect similar to the Dutch machine, and worked like it by a horse. It had an endless chain and buckets, attached to a moveable ladder, and which was capable of being elevated and depressed, according to the depth required.

It is here necessary to state, that iron buckets fixed to an endless chain, and invented by Lonce in 1747, had been used for raising earth from the foundations of the port of Dieppe, and the bridge of Orleans, so early as 1750 and 1753, under the celebrated engineers De Cessart and Perronet.

In the year 1796, Mr. Grimshaw, of Sunderland, applied to Messrs. Boulton and Watt for a steam-engine to work a dredging machine, for the purpose of cleansing the harbour of Sunderland ; the result was, the erection, by that firm, of a four-horse engine in a flat-bottomed vessel, sixty feet in length, twenty feet in width, and six feet in depth, four feet in draught ; the engine and machinery weighed twenty-three tons, and was calculated to work four spoon dredges, each containing one ton of soil, to the height of ten feet per minute.

This machine was seen by the present Mr. Watt, about the year 1797, and the experiments on its capabilities were made by the late Mr. Southern, whose able assistance and services Messrs. Boulton and Watt were always ready to acknowledge.

The following is a copy of Messrs. Boulton and Watt's memorandum book, dated 17th June, 1796.

“ Mr. Pickernall asked for the following information for a dredging machine for Sunderland Harbour.

“ An engine is wanted to work the spoons which are at present worked by men, for cleansing the harbour; these spoons are in the form of a truncated cone, the narrow end of which is closed, and to the other or open end is fixed a spade-bit; these spoons are made of a hide of leather, having an iron rim.

“ The engine is to be fixed in a boat 20 or 22 feet wide, 60 feet long, and depth at pleasure; is to work four rollers, each for a spoon.

“ These rollers are to go 10 feet per minute, and to be 12 feet above water's surface; to work in water never deeper than 10 feet, suppose a 3 feet stroke engine; the spoons at present contain only about 15 cwt., but they may be made to contain $1\frac{1}{2}$ tons; suppose all working together, say 6 tons 10 feet per minute, 134,400 lbs. one foot high per minute; but Mr. Pickernall said if they contained one ton they would be large enough. Say a four-horse engine, as it will hardly ever happen that they will be lifting them all vertically at once, $12\frac{1}{8}$ cylinder, 3 feet stroke, 30 strokes per minute, bell crank engine.”

It is clear, therefore, that Messrs. Boulton and Watt are entitled to the first claim of having applied the steam engine to dredging.

In the year 1802, the late Mr. Rennie, in his Report to the Hull Dock Company on the best mode of improving the Docks, proposed applying the six-horse engine, then employed for driving the piles of the cofferdam of the entrance*, to the old dredging machine of Grimshaw. The machine, which was made by a Dutch millwright, the only one in England, consisted of an endless chain, to which eleven wooden buckets, fastened and edged with iron, were attached, and revolved over rollers placed at the upper and lower extremities of a wooden frame or ladder, the upper roller being worked by wheels which communicated with a horse wheel. The machinery was fixed in a barge sixty-one feet six inches in length, and twenty-two feet six inches in width, and draft of water four feet; it worked in a depth of fourteen feet until the year 1814, when various alterations were made in it under the direction of the late Mr. Rennie, who caused the six-horse engine to be erected in it in the year 1804,—after which it raised from 20,000 to 23,000 tons of mud per annum, at a cost of about three pence per cubic yard, from a depth of twenty-two feet. This machine was replaced by a new and more powerful one in the year 1807.

* The piles (600 in number) for the cofferdam of the Wapping entrance of the London Docks, constructed by Mr. Rennie, were driven by one of Boulton and Watt's eight-horse engines, in the year 1801.

In the year 1802, a dredging machine, worked by horses, and similar in principle to the Hull machine, but with improved cast iron machinery, was constructed under the direction of the late Mr. Rennie, for Messrs. Perry and Wells's Dock at Blackwall, but, in consequence of the purchase and subsequent alteration of the dock by the East India Company, the machine was no longer required. The annexed plates I., II. and III. are sufficiently explanatory of the construction of the machine.

In the year 1805, the attention of the Trinity Board having been directed to the great accumulation of the shoals in the River Thames below Blackwall, advertised for tenders for removing the same. The consequence was, the sending in of numerous plans and projects of machines, most of which were referred to Mr. Rennie, and who reported unfavourably of all.

The advertisement of the Trinity Board, however, seemed to have excited the emulation of engineers, for in the years 1805, 1806, and 1807, various projects were carried into execution by Messrs. Jessop, Trevethick, Hughes, Mills, &c.

In 1804, the late Mr. Jessop made a complete set of drawings for a dredging vessel for the Caledonian Canal, which drawings are still extant. The vessel which was built in 1805, was, however, caught in a storm on one of the Highland lochs before any use had been made of it. The vessel was soon replaced by a new one on the same plan, and answered very satisfactorily. A letter from Mr. Jessop, dated 25th Feb. 1805, shews that he adopted the principle of the Hull machine as the groundwork for the steam machine.

Similar machines were shortly afterwards ordered for Sunderland, Aberdeen and Blackwall. The latter machine had attached to it a strong apparatus for splintering rocks and large stones which could not at that time be otherwise removed.

It consisted of a cast iron weight or ram working in guides and armed with a steel chisel. An iron cylinder was also used, which had a skirt of strong curves attached to it, and which could be lowered down to the surface of the rock. The water was then pumped out of the interior of the cylinder, by which contrivance workmen could descend into the bottom, and thus remove the fragments broken off by the ram.

This apparatus answered very successfully in removing the celebrated Blackwall rock, under the direction of that eminent engineer.

The first dredging machine buckets were made of hoop iron with wooden backs, and the shape was the same as those now used. Subsequently the buckets were made wholly of iron, built in the same way, until boiler plates became more common.

In the letter from Mr. Jessop, giving instructions for the making of his first dredging machine, he says, "the engine will be six horses power when they are

worked by horses; if the buckets lay hold too hard, the horses will stop, but it would not be easy to stop a fly-wheel, and something must break or yield.

“It occurs to me that to provide for this, that part of the fly-wheel shaft on which the pinion is fixed should be turned, and the pinion so fixed on it by a spring socket and screws as to be firm enough for its proper work, but to turn round when hard strained.”*

The next in chronological order are the claims of the late ingenious Richard Trevethick.

The following are extracts from several letters written by him in the year 1806. At the end of a letter, dated 18th February, 1806, respecting a *puffer* engine, directed to the late Davies Gilbert, Esq., M.P. :—

“I am about to enter into a contract with the Trinity Board for lifting up ballast out of the bottom of the Thames for all the shipping. The first quantity stated was 300,000 tons per year, but now they state 500,000 tons per year. I am to do nothing but wind up the chain for sixpence per ton, which is now done by men. They never lift it above twenty-five feet high: a man will now get up ten tons for seven shillings. My engine at Dalcoath has lifted above 100 tons that height with one bushel of coals. I have two engines already finished for the purpose, and shall be in town in about fifteen days for to set them to work. They propose to engage with me for twenty-one years. The outlines of the contract they have sent me down, which I think is very fair terms, and thank you for your answer before I leave this county.”

(Signed) RICHARD TREVETHICK.

Mr. Gilbert used to relate the dismay which the constant breaking of the chain and buckets caused to Mr. Trevethick on the first trial of his dredging machine, and the subsequent delight he experienced when he had overcome the difficulty with stronger tackle.

The money for these trials was found by some capitalists, with whom Mr. Trevethick subsequently quarrelled, and the *Blazer* and *Plymouth*, the vessels in which his engines and machinery were fitted, fell into other hands.

In a letter, dated August 1, 1807, Trevethick speaks of his having closed an agreement to superintend driving a level under the Thames, and of the remuneration he was to receive: he adds, “it will be very easy for me to attend, as I must be always near the spot to attend to the engines on the river.” The last words of the two letters, dated 28th August, 1807: “The engines on the river go on as usual.”

* The Editor is indebted to Joseph Glynn, of Butterley, for the above facts.

12th September, 1807. "The engines continue to get on as usual on the river. The great engine is not yet at work, but hope it will be soon completed."

In the same year, 1807, Messrs. Bough, Hughes and Mills requested Mr. Walter Hunter (who had previously been in the service of Mr. Rennie on the Hull Dock and Messrs. Perry and Wells's machines) to erect a dredging machine in a gun brig which they had bought, called the Plymouth; the same vessel which had previously been employed by Trevethick. Mr. Hunter made drawings for a machine for working a set of buckets on each side of the vessel for a steam-engine of twenty-horse power by Messrs. Fenton, Murray, and Woods, of Leeds, and which was finally erected by Mr. Hunter, partner of Mr. English, (who was also in the employment of Mr. Rennie,) in the Plymouth dredger, which was afterwards employed by the government at Woolwich.

Among other schemes for dredging, and towards which Mr. Rennie's attention had been directed, was one of Mr. Shorter's dredging machines, consisting of two large spoon dredgers, set in motion by the current of the tide impinging upon a screw wheel seventeen feet in diameter, and making four revolutions per minute. Its circumference moved at the rate of 213 feet per minute, so that the velocity of the wheel was greater than that of the tide, which ran on the occasion of making the experiment, April 20th, 1805, 2 miles per hour, or 176 feet per minute. This difference was attributed to the vanes having too great an angle at their extremities, and too great a portion of the whole area of the circle opposed to the current being filled with the vanes. Mr. Rennie, therefore, directed four vanes to be taken off, when the wheel, not performing any work, made exactly the same number of revolutions as before, but on loading the machine the effect was considerably less. In the first case the area was too much, in the second too little. The real area which produced the maximum effect was four-fifths, and although he was of opinion that the machine might have been considerably improved, he did not estimate it, with a mean tidal velocity of current of two miles per hour, at above one and a half horse power, and taking into account the inconvenience of the application, and the expense of attending the machine, he did not deem it worthy of the patronage of the Trinity Corporation. The following is an abstract of the experiments which were made by Mr. Rennie.—Report to the Chairman of the Trinity Board, Joseph Cotton, Esq., date, 1st May, 1805.

EXTRACTED FROM MR. RENNIE'S NOTE BOOK.

"Blackwall, April 20th, 1805.

"1st *Experiment*.—Shorter's fan wheel machine made four revolutions per minute; when one bag was filling, it made two; when pulling up, three and a quarter.

"*2nd Experiment.*—When working, made four revolutions per minute; when both bags were filling, it made one revolution in sixty-five seconds.

"When the bags were disengaged from the bottom it made three revolutions per minute, and took seven minutes to fill and empty two bags.

"*3rd Experiment.*—Took off four of the flies from the wheel and tried the machine empty, it then made four revolutions per minute. But on both spoons being put on, it made one revolution in two minutes; when the bags were taken up, one was nearly full, the other one-third full; when they were both suspended in rising, the machine stopped. In this last experiment, the machine worked with four vanes only. Each vane was seven feet and a half radius to the shoulder, or six feet three inches wide at the extremity.

"Shorter, the maker, says, that this machine can work three hours and a half on the ebb, and two hours and a half on the flood. But it has never raised more than thirty-five tons in two hours and a half, and loaded only one barge. Three men attended. The vessel has four spoons, but it is not long enough for so many. It being neap tide at the time the experiments were made, and the strength nearly spent of course, the effects of the machine were much less than might have been the case had it been at the time of springs. But even with all this, it is pretty evident that the machine would not have had any very effective power. The vanes in the first experiment filled too much, and in the second too little; of course they had not a fair trial in either case. Their angles were bad, and they had no transit, and therefore great resistance was presented to their moving through the water. The tide, I apprehend, in its greatest strength, will move at little more than three knots per hour, which is only equal to a head of seven inches and a half, but as the velocity for a considerable part of the tide is not half what is stated above, it is evident that no great power can be expected from such a machine. In strict theory, a head of four inches would produce it. A wheel seventeen feet diameter, making five revolutions per minute, moves at the rate of 16,020 feet per hour, which is as the velocity of the water; 15,540 is 480 feet faster than the water; no great additional velocity can be expected. The total area of the whole circle is 227 feet, that of the 4 vanes is 127, say 120."

According to Mr. Herbert, the Secretary of the Trinity Board, to whom the writer of this is indebted for the information, a dredging machine, invented by Mr. Trevethick, was used between 1806 and 1807, and subsequently one by Mr. John Mills, worked by a steam engine, but this was not resorted to by the Board after 1810, and it was not till 1826 that the Corporation employed a steam dredger of its own. From the year 1805, the value of the steam dredging machine became

gradually known. The old Hull machine was replaced by a new machine of six horse power under Mr. Rennie's direction, in 1807 and 1808. Others were made for various ports, docks, and rivers in which he was concerned in Greenock, Liverpool, Portsmouth, Port Patrick, Donaghadee, Boston, Kennet and Avon Canal, Ramsgate, &c., besides many others for foreign countries, such as Amsterdam, Barcelona, Calcutta, Malaga, Cronstadt, Valentia, &c., without mentioning many others, which were made in Glasgow, Liverpool, Butterley, &c., and at present every harbour is considered incomplete without one.

The performance of these machines rarely exceeds fifty per cent. of the power expended. This arises from the complexity of the machine, and the varying nature of the soil.

A good dredging machine ought to raise from a depth of 25 feet from 150 to 200 tons of gravel per hour when properly worked, or a ten horse power will raise from 90 to 100 tons per hour about thirty-four feet in height, or 700 to 800 tons per day, being at the rate of 10 tons of materials per horse power per hour.

Dredging machines have been constructed in various ways, and of iron or wood, according to the nature of the service. Some machines have been arranged so that the system of chain and buckets should work through a channel in the middle of the vessel; others with one system on each side; and others with the buckets working over the extremity of the vessel. But, in general, the modern practice is to place the machinery towards one extremity of the vessel, to allow of the working of the ladder (which holds the buckets) freely on either side of the vessel. By this arrangement barges can be laid along both sides of the vessel, and the material raised by the machine be taken away more easily. The machinery consists of upright and horizontal shafts, on which bevil wheels, together with the reels or barrels, are fixed for working the chain and buckets, which latter, by being pointed with steel, dig into the soil, which is raised to the upper reels, whence it falls down an inclined board or shoot into the barges. These reels or barrels are made to disconnect by means of friction clutches, so that either or both sets of buckets may be stopped at pleasure, or in case of any obstacle, such as an anchor or a stone intervening, the friction clutch allows the reels to slip, and thus prevents the machine from breaking. The ladder containing the chains and buckets can be raised or lowered to suit any required depth, and the feeding of the buckets can be regulated by means of a windlass, which is worked by the engine.

The buckets, which are now made with boiler plates, hold from five to six cwt. of material.

The dredging machine has been employed very advantageously in raising mud,

sand, gravel, and even chalk, from different harbours and rivers, both at home and abroad.

In the Clyde, the Thames, the Witham, the rivers and canals of the Helder Canal, in Holland, &c., the dredging machine has been invaluable, and so important are its services in hydraulic engineering, that there is scarcely a port or harbour in the United Kingdom, such as Portsmouth, Chatham, Ramsgate, Liverpool, &c., in which it has not been most beneficially employed.

EXPLANATION OF THE PLATES.

PLATES I. AND II.

MACHINE FOR RAISING MUD OUT OF MESSRS. PERRY AND WELLS'S DOCK AT BLACKWALL.

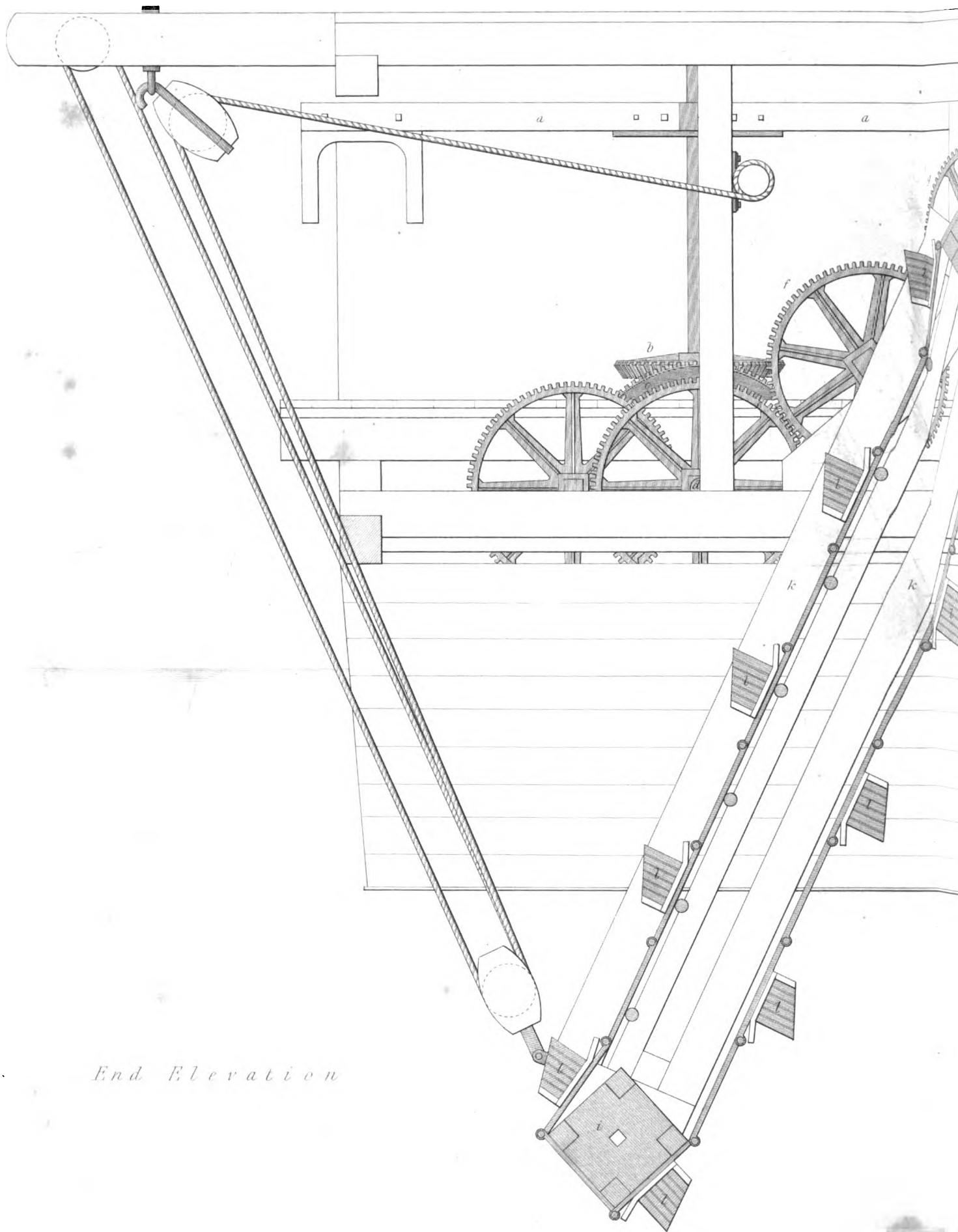
- a.* Horse-bar.
- b.* First motion bevil wheel for transferring the vertical motion given by the horse-bar to the horizontal one required.
- c.* Corresponding bevil wheel on horizontal shaft.
- d.* Horizontal shaft, on which is fixed
- e.* A spur wheel.
- f. g.* Are two spur wheels, by means of which motion is given to
- h.* Reel shaft.
- i.* The reels are at each end of the ladder round which the buckets pass.
- k.* The ladder, which can be raised or lowered by the tackle to the required depth.
- l.* The buckets for raising the mud.
- m.* A shoot for delivering the mud from the buckets into
- n.* A barge alongside.
- o.* A trap door at the bottom of the bridge for discharging the mud.
- p.* A pinion on horizontal shaft for working the windlass, by means of which, as the dredging progresses, the machine is hauled ahead.

PLATE III.

- a.* The cylinder of steam-engine.
- b.* The boiler.
- c.* The crank shaft, on which is fixed a bevil pinion *c'*, worked into
- d.* A bevil wheel on upright shaft, on which is also
- e.* A bevil pinion working into a bevil wheel *e'*.
- f.* The reel shaft.
- g.* The reels round which the bucket passes.
- h.* The buckets for raising the mud, &c., running upon rollers fixed upon
- i.* The ladder, which can be raised or lowered by means of the tackle to the required depth.
- k.* Worm on upright shaft for working the wheel *k'* on roller shaft, by means of which, as the dredging progresses, the machine is hauled ahead.

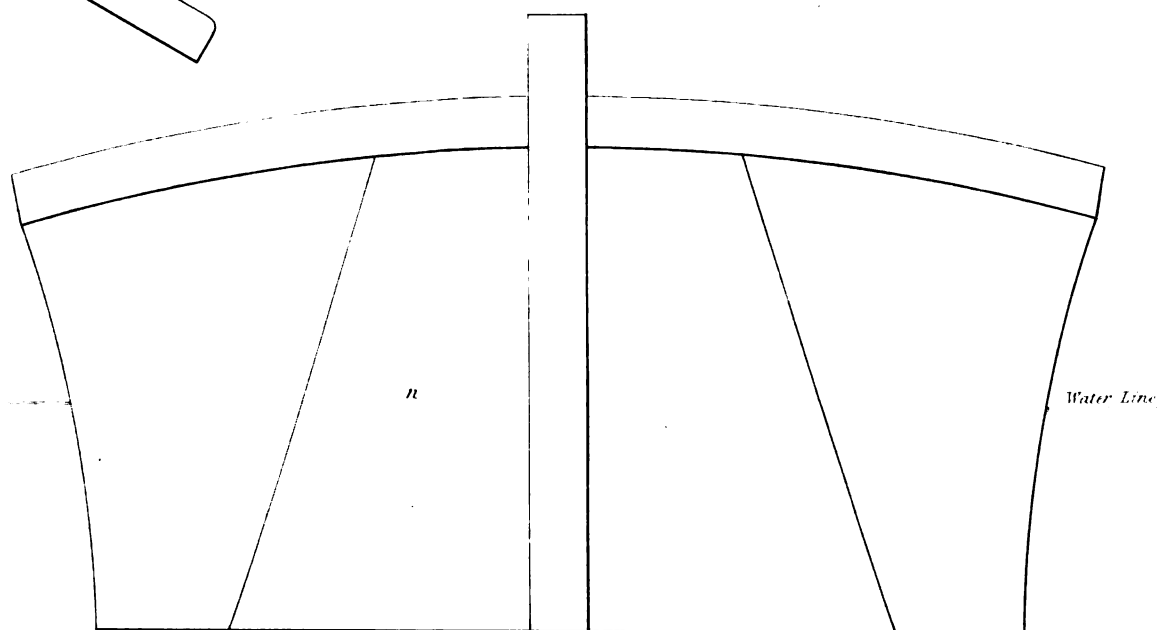
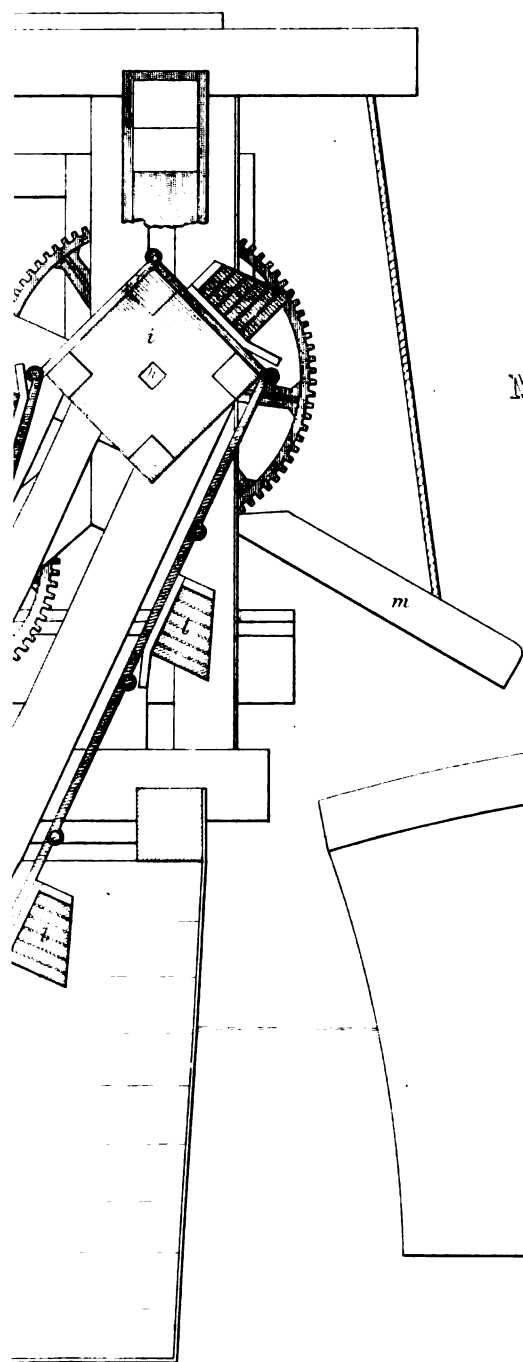
In concluding this article, we must not omit to record our thanks to George Rennie, Esq., for his kindness in this as in many previous instances: we are indebted to him for data and the correction of some important references.

The subject is to be resumed in the Second Part, by examples of recently constructed machines.



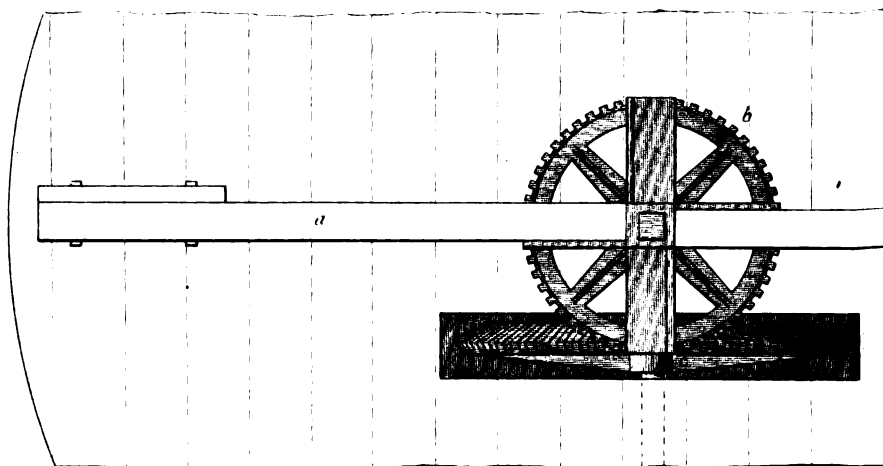
End Elevation

MACHINE FOR RAISING MUD OUT OF
MESSRS PERRY & WELLS'S DOCK AT BLACKWALL.

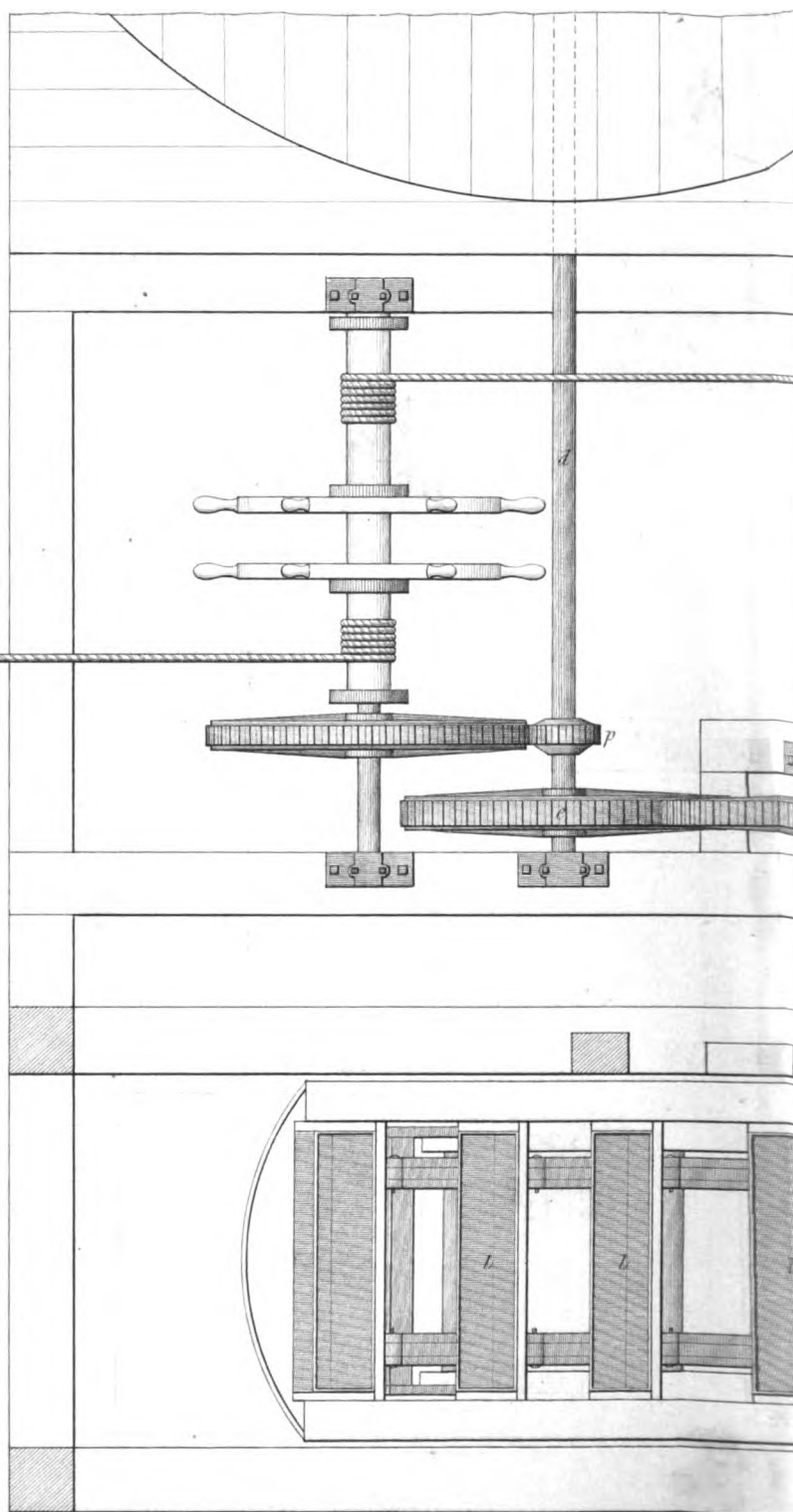


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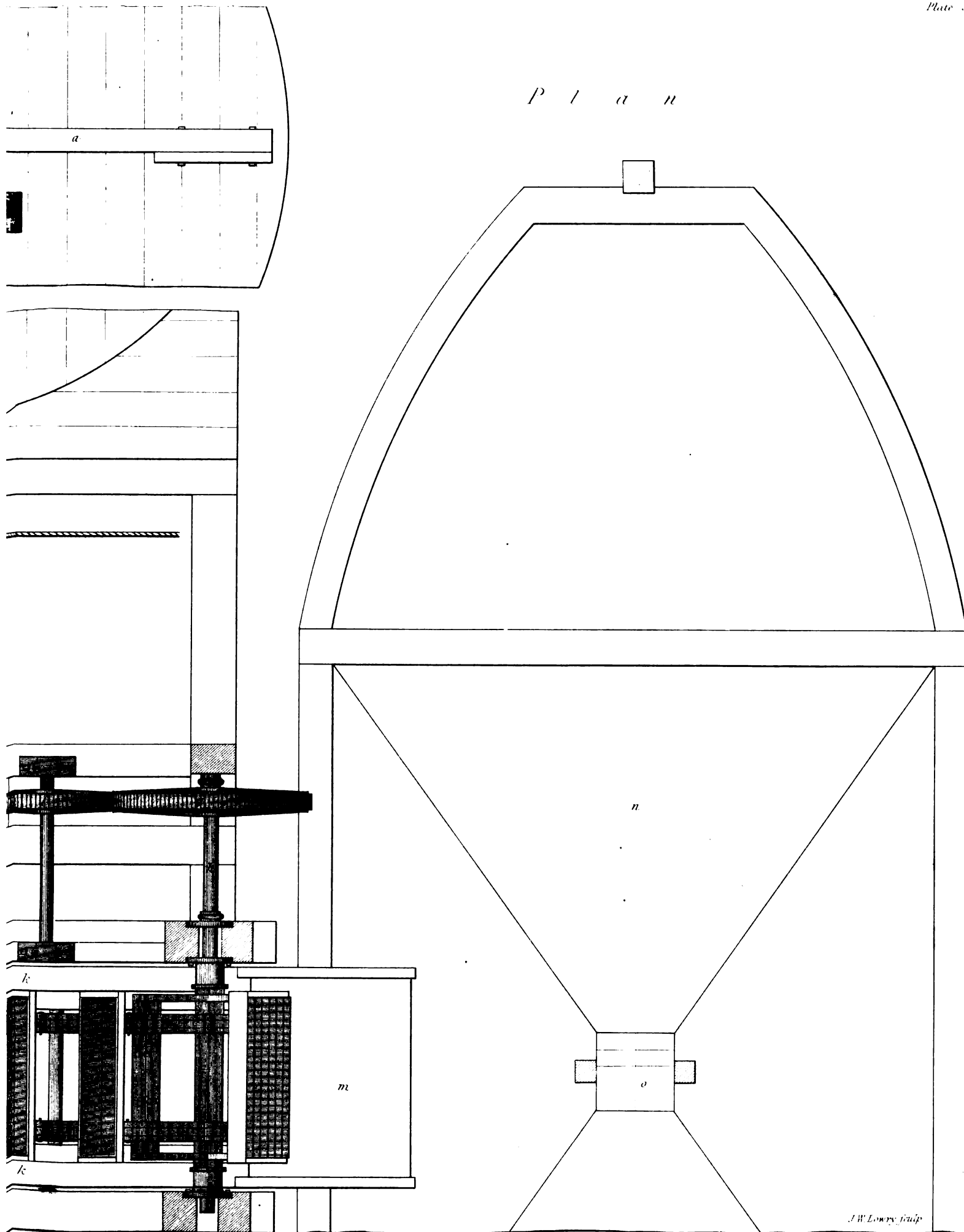
JW Lowry, fecit

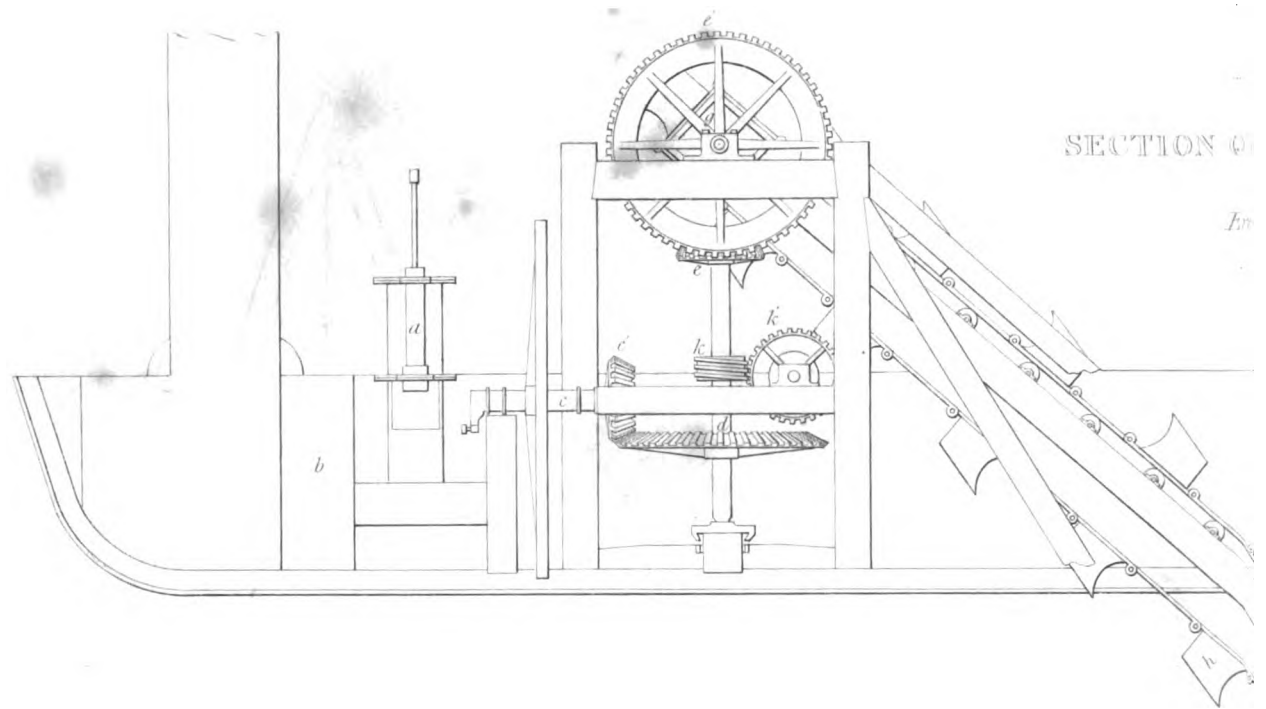


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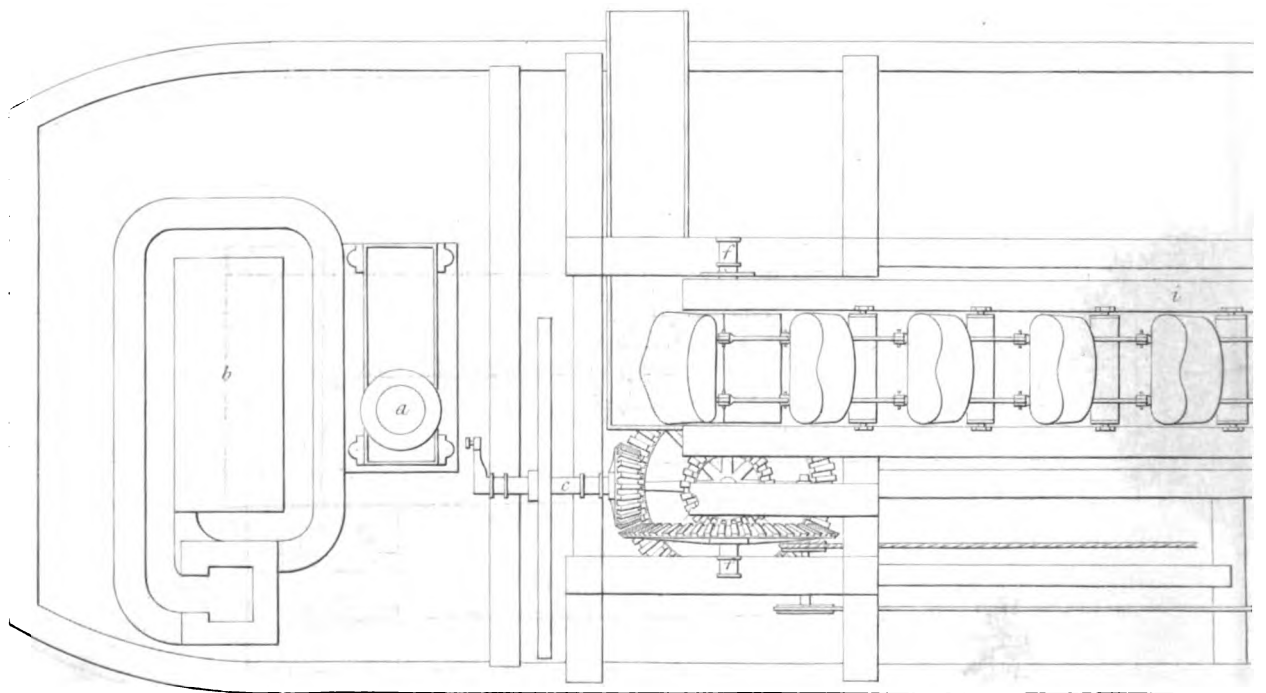
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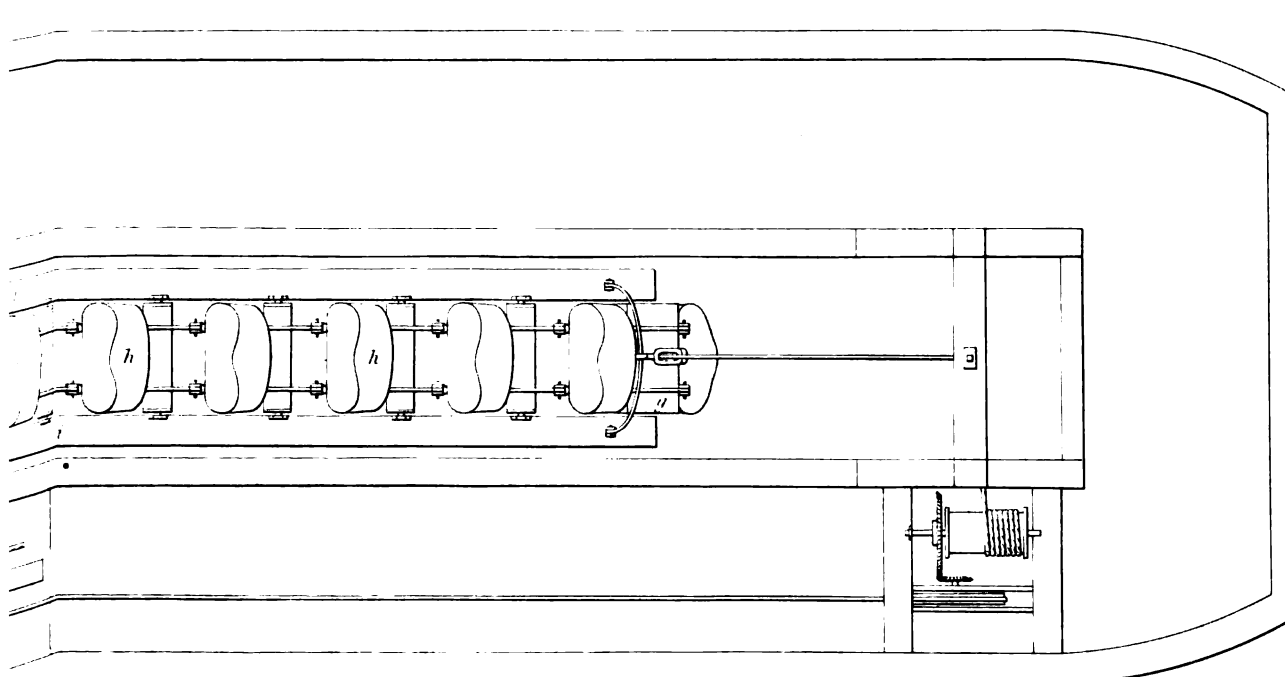
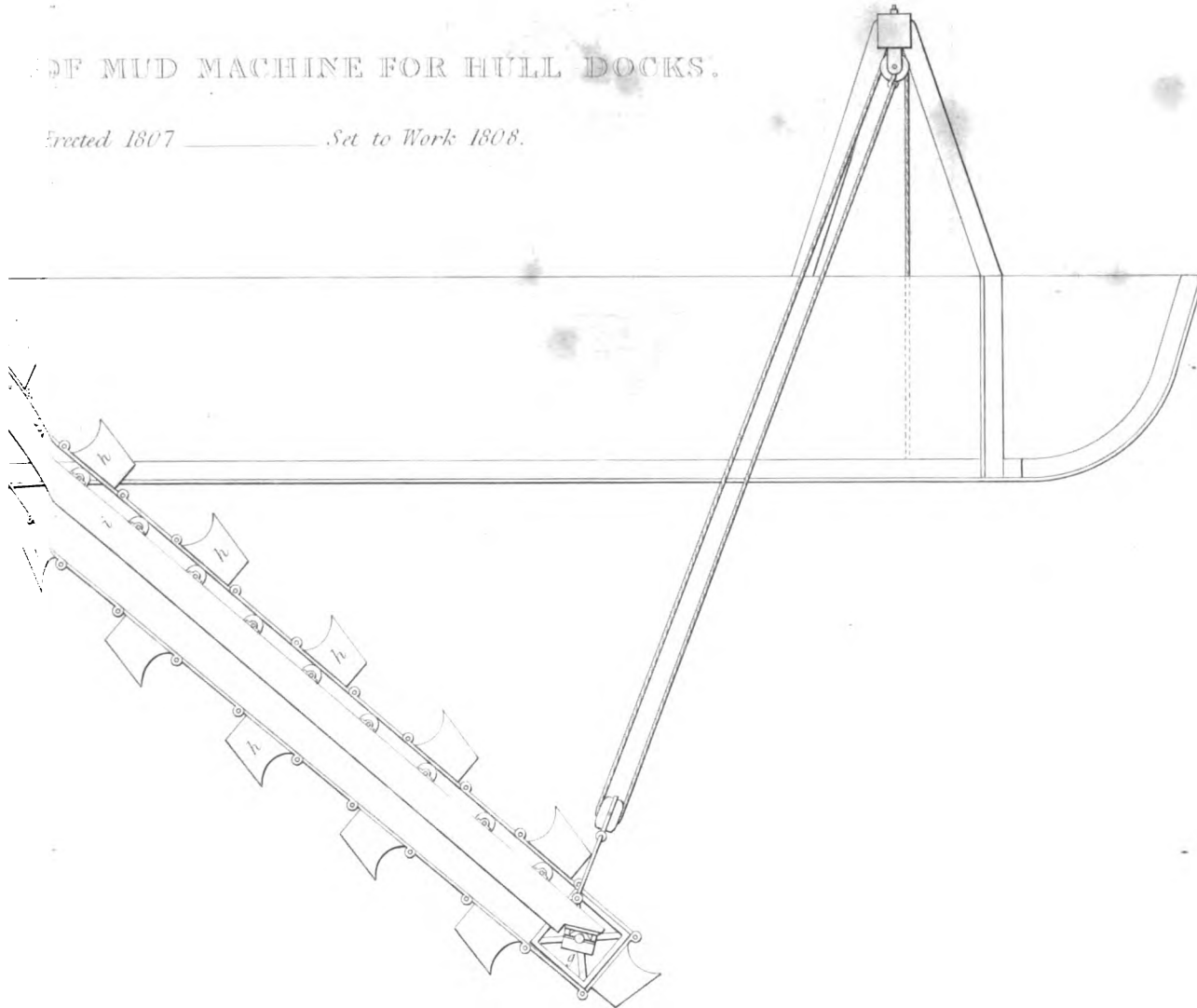
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Published by John W.

OF MUD MACHINE FOR HULL DOCKS.

Erected 1807 ———— Set to Work 1808.



JW Lowry fecit

made at 11843 London

THE ENGINES
OF THE
RUSSIAN STEAM FRIGATE OF WAR KAMSCHATKA,
CONSTRUCTED AT NEW YORK, FOR THE RUSSIAN GOVERNMENT.

THE accompanying engravings, made from drawings furnished by Messrs. Schuyler of New York, together with a letter descriptive of the same, will be examined with interest, as exhibiting modes of operation quite new on this side of the Atlantic, and as also shewing a principle of boiler construction, singular in itself, and peculiarly valuable at the present time as demonstrating the efficacy of anthracite coal combustion, for the greater production of heat, saving in consumption, and consequent diminution of expense. In Part II. of this work we shall be enabled, by the liberality of the Russian government, to place before our readers results that will be very creditable to the scientific gentlemen employed on the construction of these engines. We shall give statistics of the performances of the vessel, and all particulars respecting her present efficacy and stability.

NEW YORK, November 28, 1842.

DEAR SIR,

YOUR letter of the 31st October has been received, and by the steamer Acadia, of the 1st December, we send you the four accompanying drawings of the engines and boilers of the steam ship Kamschatka.

The drawings have been made from the working draughts, and present every thing that is necessary for a full comprehension of this form of marine engine. We shall merely call your attention to those particulars in which it differs from English engines for the same purpose, giving you our reasons for having preferred it in planning the Kamschatka.

In the United States, the most approved method of using steam is expansively,
ENG. IV.

B

that is to say, by having a high pressure in the boiler, cutting off the steam from the cylinder after the piston has performed say one quarter of its stroke, and allowing this high steam to expand through the remaining three quarters of the stroke. To this system to work to the best advantage very long cylinders are required.

Having determined upon adhering to this method, so successful in our river steamers, it became necessary to adopt some plan by which the length of cylinder could be preserved without elevating the engines above the deck, or cramping the action of the connecting rod, as is seen in some English government steamers. By reference to the drawing, you will observe that any desired length of stroke can be obtained without adding to the elevation of the engines, and also that the connecting rod has great length and free action. The advantages of placing the cylinders in a horizontal position, firmly secured to the keelsons, and bolted down through the hull, are also very great. The strain of the engine is fore and aft, which tends greatly to relieve the ship.

The engine takes up much less space in width than any other; there is consequently room for coal-bunkers four feet wide on each side, thereby rendering the engines completely shot proof.

You will likewise observe, that in this plan we retain vertical air pumps, force pumps, and valves. The steam and exhaustion valves are of the kind commonly used in the United States, known as double balance valves. The valves used for expansion are of our own contrivance, and peculiar to this ship; they are worked by a separate eccentric and rocker shaft, which is so set as to follow the motion of the steam valve, cutting off the steam at any point of the stroke which may be desired; they can be thrown out of gear instantaneously, without stopping the engine. You will likewise observe that the arrangement of the feeding apparatus is such, that the whole is under the immediate supervision of the engineer on duty, and that he in person regulates the feeding and blowing off of the boilers—a matter which we deem of great value.

The frame is of cast iron; the columns and cross braces are hollow, and have wrought iron screw bolts running through them. These wrought iron bolts pass through the keelsons of the ship from the outside, and, after every thing is in place, are screwed up as tightly as they can be drawn; thus attaching the whole frame firmly to the keelsons without any connexion with the sides of the ship.

You will also observe, that the triangle or half beam, which forms the connexion between the piston rod and the connecting rod and cranks of the engine, can be so arranged, by altering the centres, as to make the cranks of any length which is thought most advisable, without reference to the length of stroke of the piston.

In the case of the Kamschatka's engine, the cylinders have ten feet stroke, while the cranks are but four feet in length, and you will readily perceive that any leverage lost in shortening the crank is exactly counterbalanced by the gain upon the half beam.

The boilers of the Kamschatka we consider worthy of some attention in England, as they are particularly constructed for burning anthracite coal, which we are informed you have in great abundance, though as yet untried. The advantages of using anthracite coal in war steamers, provided it can be done with the same economy as the bituminous coal, are as follows :

1. The absence of all dirt, dust, and smoke. A steamer with this coal can be kept in every respect as clean, and her sails as white, as a sailing ship.
2. From the absence of sparks, removing all risk of fire from that source.
3. The very important consideration, which will scarcely be appreciated until a time of war, that all the motions of a steam vessel using bituminous coal will be known to an enemy by the smoke ; and that sailing vessels, in many cases, before they can themselves be seen, will have ample warning of the vicinity of steamers :—the use of anthracite coal remedies this objection.
4. Anthracite coal has more weight in the same bulk ; is entirely free from the danger of spontaneous combustion, and, owing to its hardness, does not slack from the motion of the vessel.

Having succeeded perfectly in the Kamschatka, in the use of this coal, we will call your attention to the peculiar form of her boilers, invented and patented by ourselves, and now in general use in steam boats of our construction in this country.

The cylinders of the Kamschatka are $62\frac{1}{2}$ inches in diameter, and 10 feet stroke. The steam is cut off at one third of the length of the cylinder. The number of strokes of the piston are from 26 to 34 per minute—on an average 30 ; thus requiring 4260 cubic feet of steam per minute, of an average pressure of 12 lbs. per square inch above the atmosphere.

She has four copper boilers, each 10 feet long, 12 feet 6 inches wide, and 14 feet high ; the flues all centering in one chimney, 7 feet in diameter, and 46 feet high above deck. Each boiler has four separate furnaces ; the heated current is taken from each furnace through 400 copper tubes, each 28 inches long, and one inch in diameter in the clear. From any one of these furnaces, by a peculiar construction of a revolving grate, the coals can be instantly dropped, and the tubes in that furnace can be swept out and cleaned while all the other furnaces are in active operation. Some doubts were entertained by engineers in this country as to the possibility of keeping these small flues tight, and also as to their choking up on a long sea voyage. Our experience in

the Kamschatka completely settles that point. Of the 6400 tubes in her boilers, not one is known to have failed in any respect. After passing through these small tubes, exposing an immense quantity of fire surface, the heat is carried by ordinary cross flues through the upper part of the boiler over the arch of the furnaces to the chimney.

The consumption of anthracite coal in the Kamschatka, to furnish the supply of steam above stated, varies from one ton to one ton and a quarter per hour. We would also remark, that the same boilers answer, though not so perfectly, for the consumption of bituminous coal. On the voyage from Southampton to Cronstadt the latter coal was used, the average consumption being 32 tons in 24 hours.

The plan of engine used in the Kamschatka, and known as "Lighthall's Patent," is gradually coming into general use in these waters. A new steamer for the Hudson river, now building, 325 feet long, which is expected to excel in speed all others, is to be supplied with these engines, the proprietors having already tested the plan for several years in the largest and finest boat on that river.

The steam ship Kamschatka, planned and constructed by us for the Russian government, is a man-of-war steamer of the largest class, carrying a heavier armament than any steamer, to our knowledge, now afloat. She is built entirely of American oak, copper fastened, diagonal iron bracing; her gun-carriages of African oak, and furnished and equipped in the most complete manner. She is ship-rigged, and her machinery so arranged as not in any way to interfere with the working of her yards. She is a double decker; carries on the main deck eighteen long thirty-six pounders, and on her spar deck two guns of ten inch bore, one forward and one aft, revolving in whole circles; and two guns of eight inch bore, revolving in half circles. Her length is 246 feet; beam 45 feet 6 inches; depth 24 feet 6 inches; tonnage $2049\frac{2}{5}$; draught of water with crew, ammunition, provisions, water for a cruise, and fuel for 26 days, 16 feet.

The performance of the ship, in a very stormy and tempestuous voyage from New York to Cronstadt, in the months of October and November, 1841, was entirely satisfactory. Her rate of speed was from 10 to 12, and occasionally $12\frac{1}{2}$ knots per hour. Under sail, her engines being disconnected, she has made 197 miles in 24 hours. In the heaviest weather she was steered with perfect ease, and shipped no sea during the whole voyage.

The accounts we have had of her performance this summer, received from the best sources, assure us that she continues to work in the best manner. We are daily expecting the detail of her summer's operations, which, if interesting, we will forward to you.

We hope, from this general sketch, together with the drawings, you will be able to prepare such an article as you wish for your publication ; and we shall be happy, at any time that you may desire, to furnish you with further information of the Kamschatka, or upon the subject generally of the construction of steam vessels in the United States.

Very truly,

Your obedient servants,

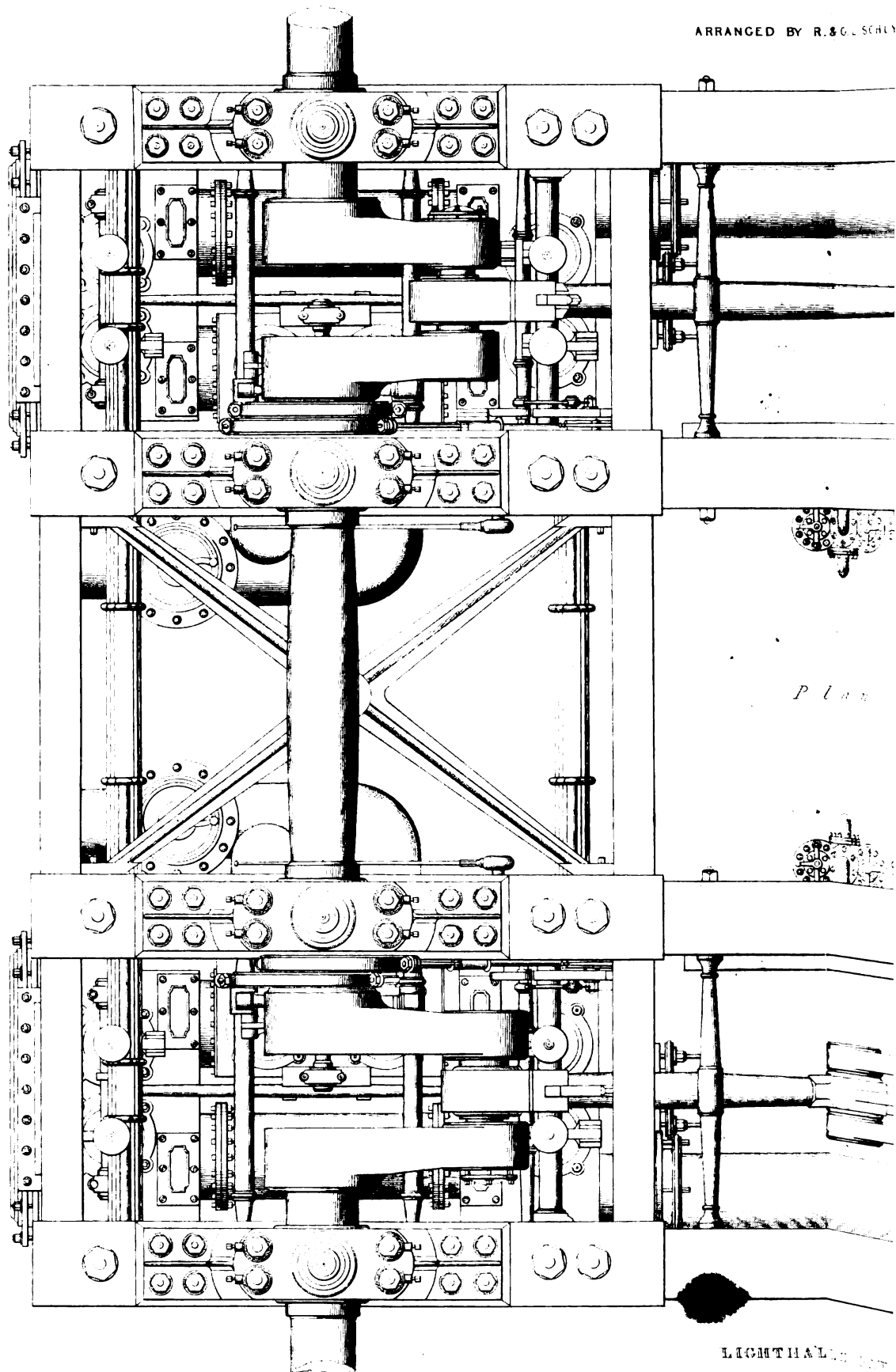
R. AND G. L. SCHUYLER.

MR. JOHN WEALE,
59, High Holborn, London.

- Plate 1. Plan of the Engines of the Steam Ship Kamschatka, arranged by R. and G. L. Schuyler, C.E.
2. Longitudinal Section of ditto.
 3. Front Elevation of ditto.
 4. Boilers of ditto, Sections and Side Elevation.

ENGINES OF THE STEAM

ARRANGED BY R. & G. SCHUY



J. H. H. H. H. H.

LIGHTHALL

London: Published by John W. & Co. 1851

BY STEEL KAMSCHEATKA.

L. SCHUYLER, C.E.

Fig. 1

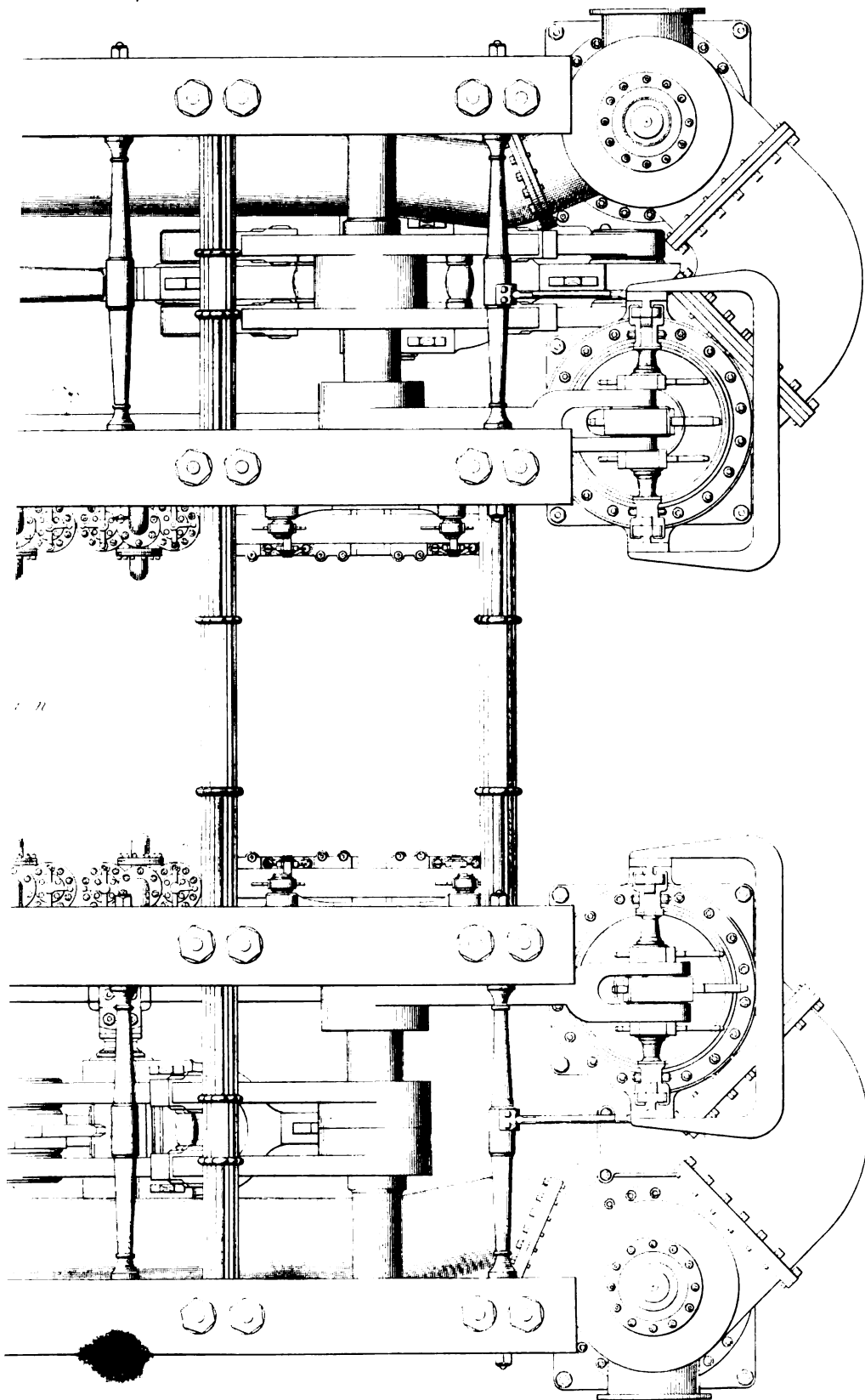
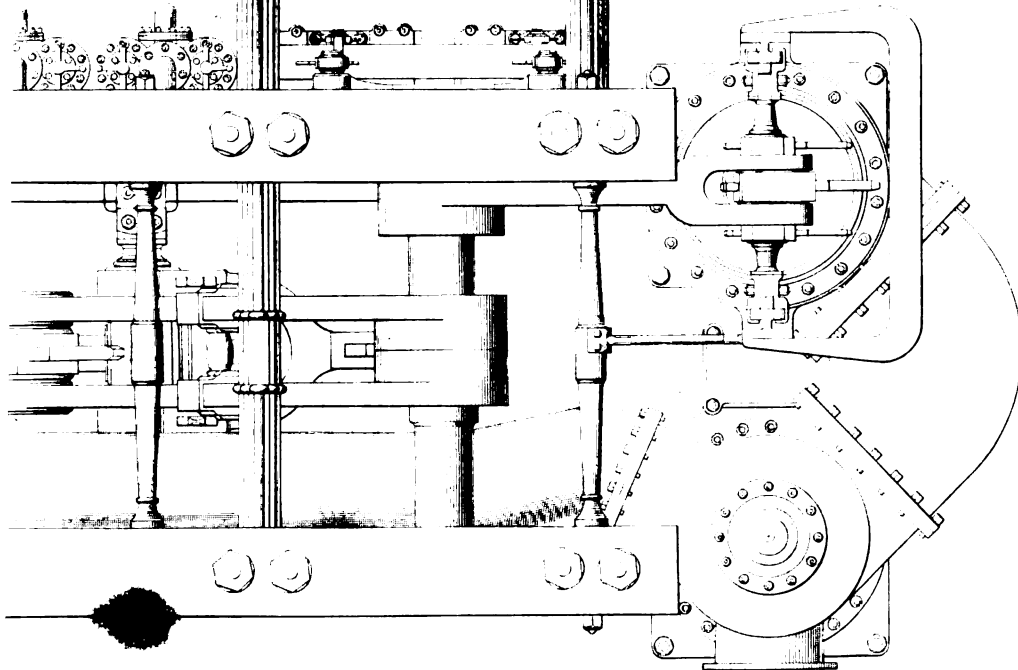
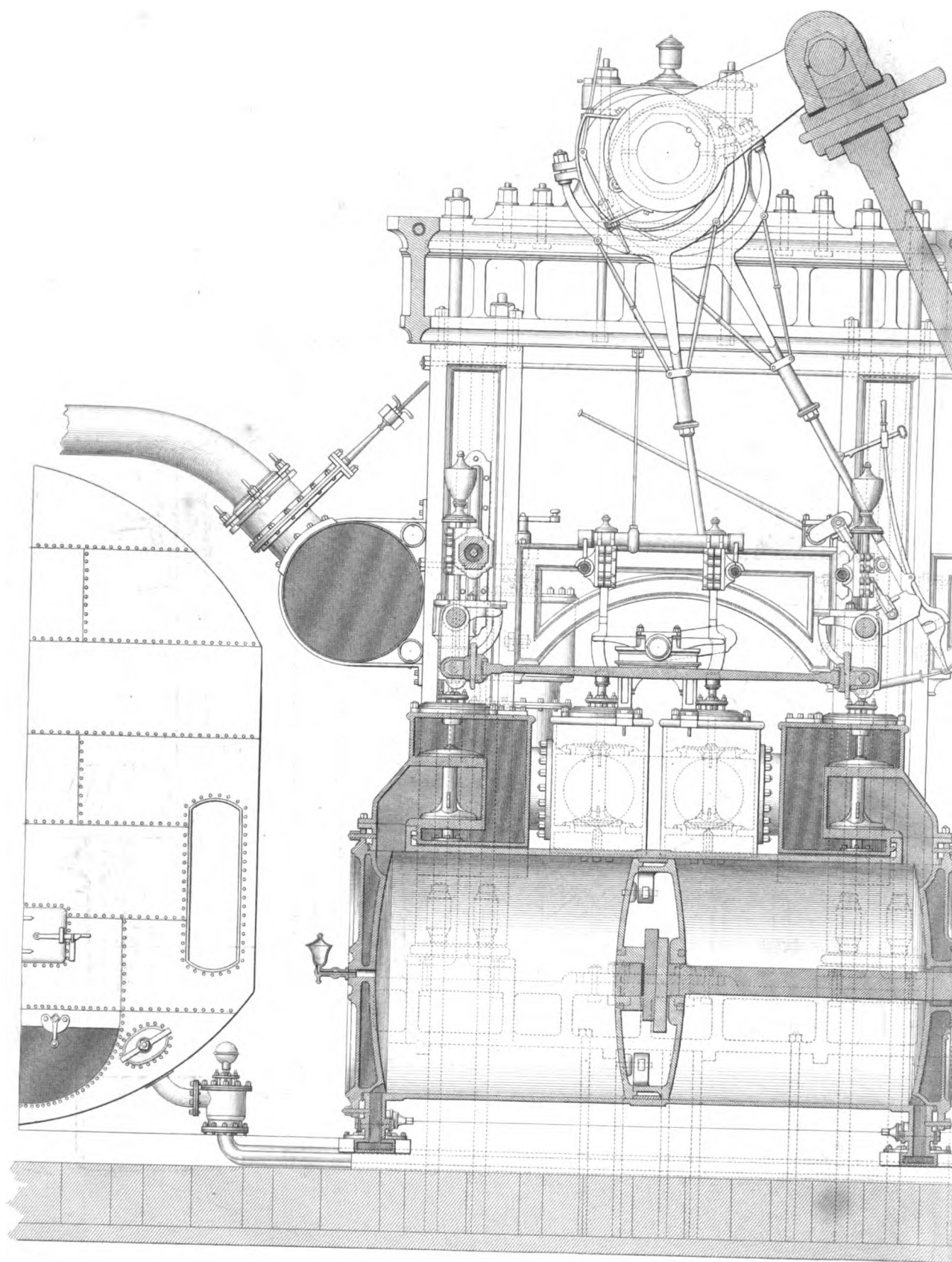


Fig. 2



U. S. PATENT.

J. A. Henry, fildp

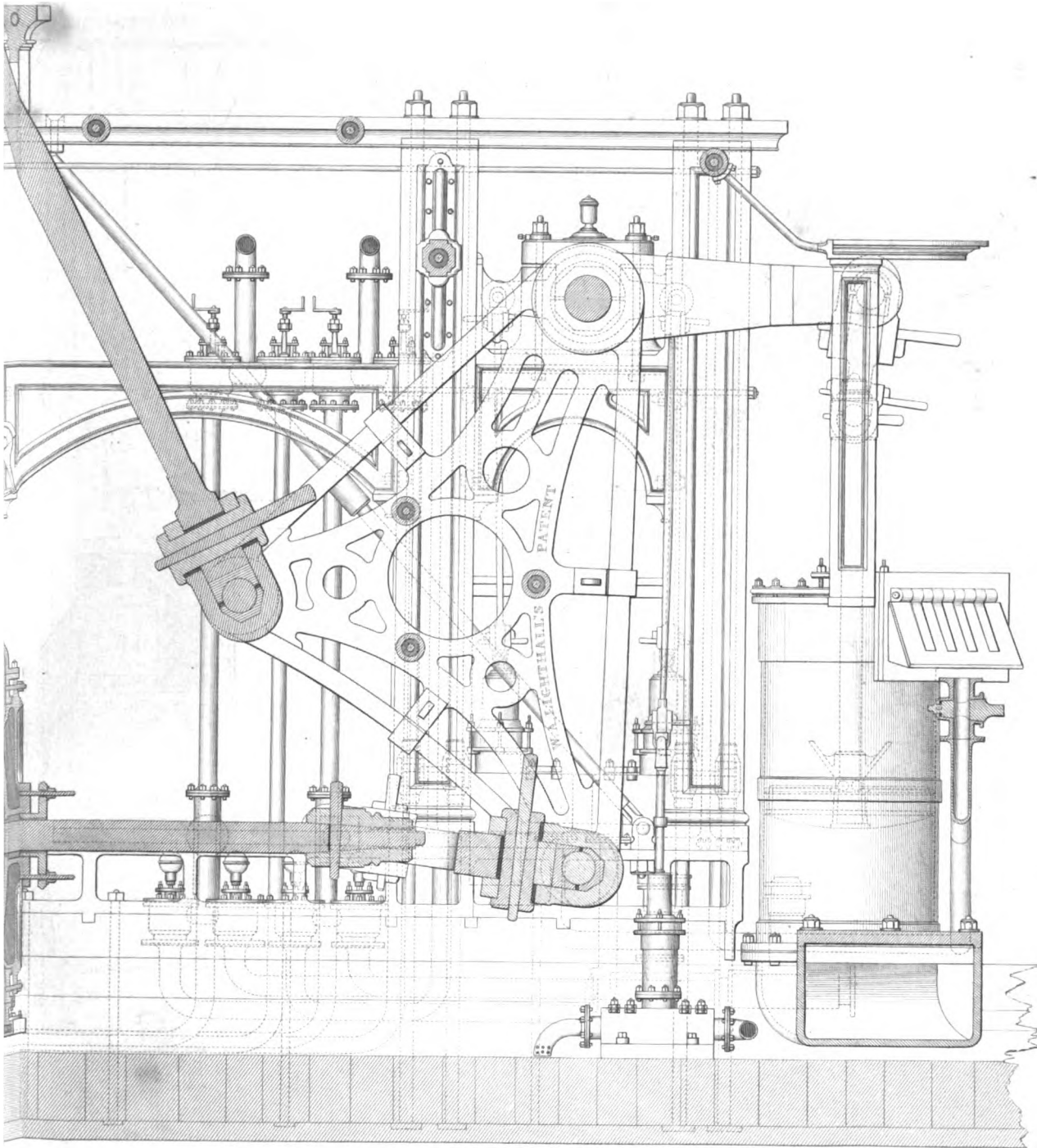


Longitudinal

London: Published by John W. & Co. 1884.

ENGINES OF THE STEAM SHIP KAYECHATKA

ARRANGED BY R. & G. L. SCHUYLER, C. E.

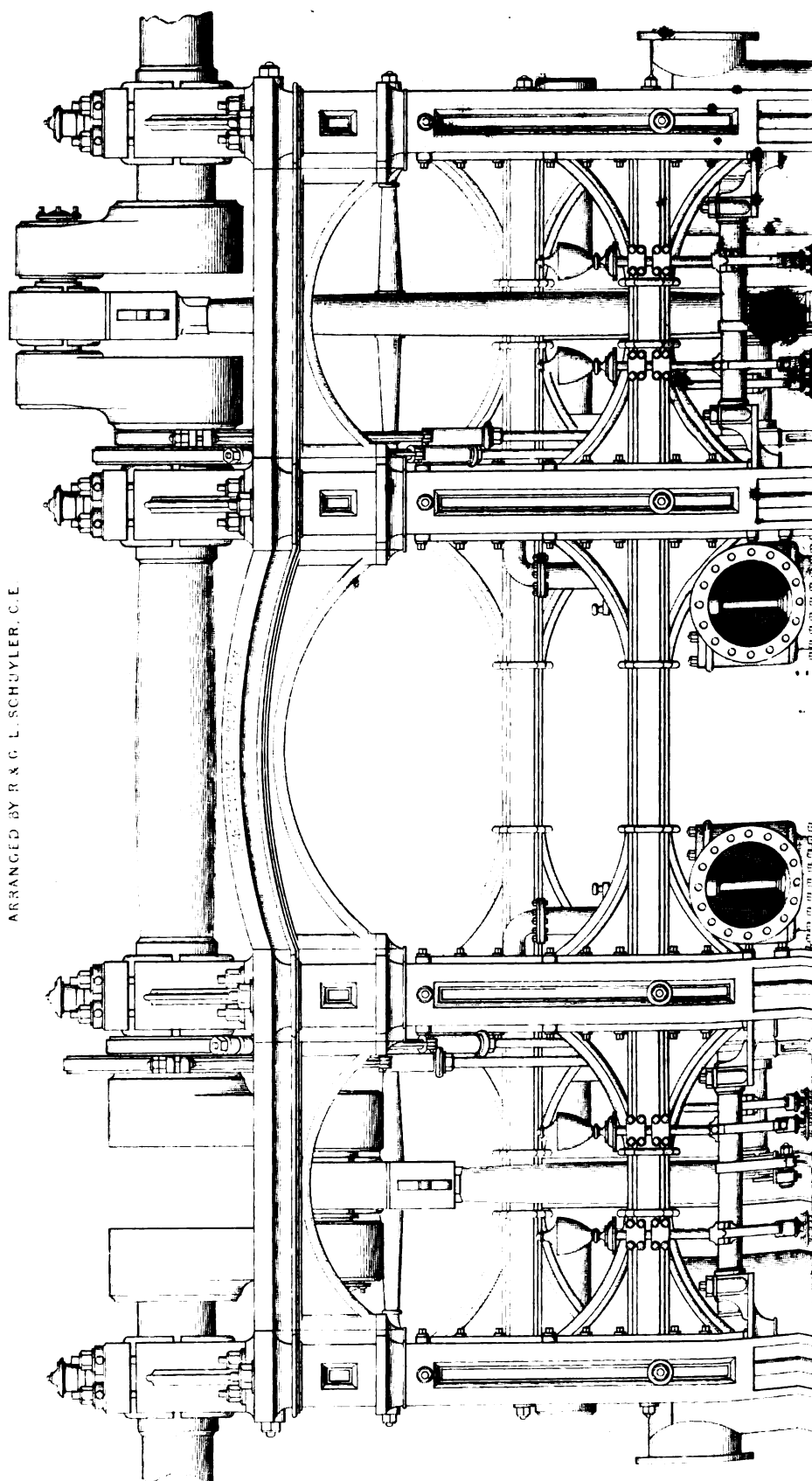


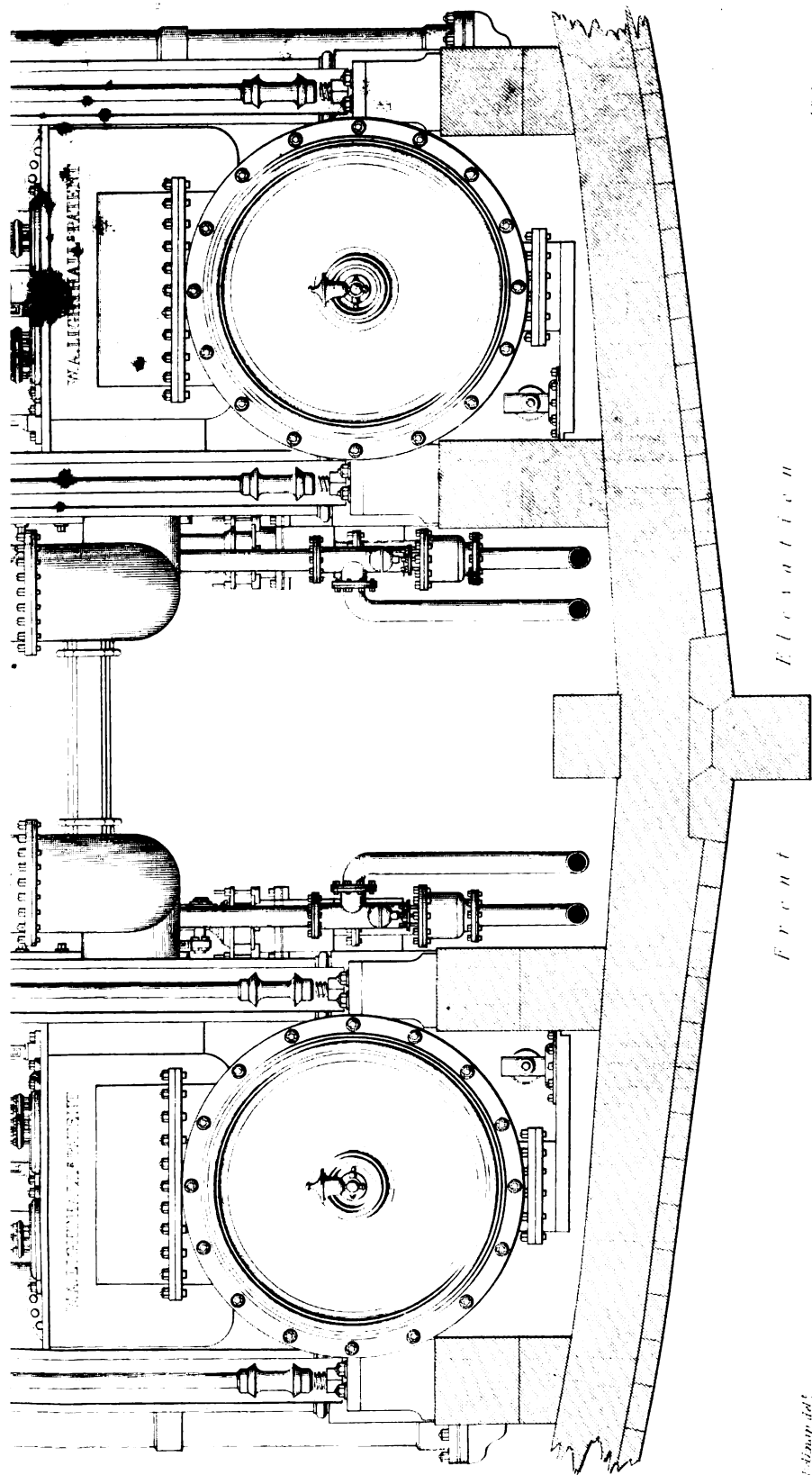
Abstract

J. W. Long, fmr.

ENGINES OF THE STEAM SHIP KANISCHATKA.

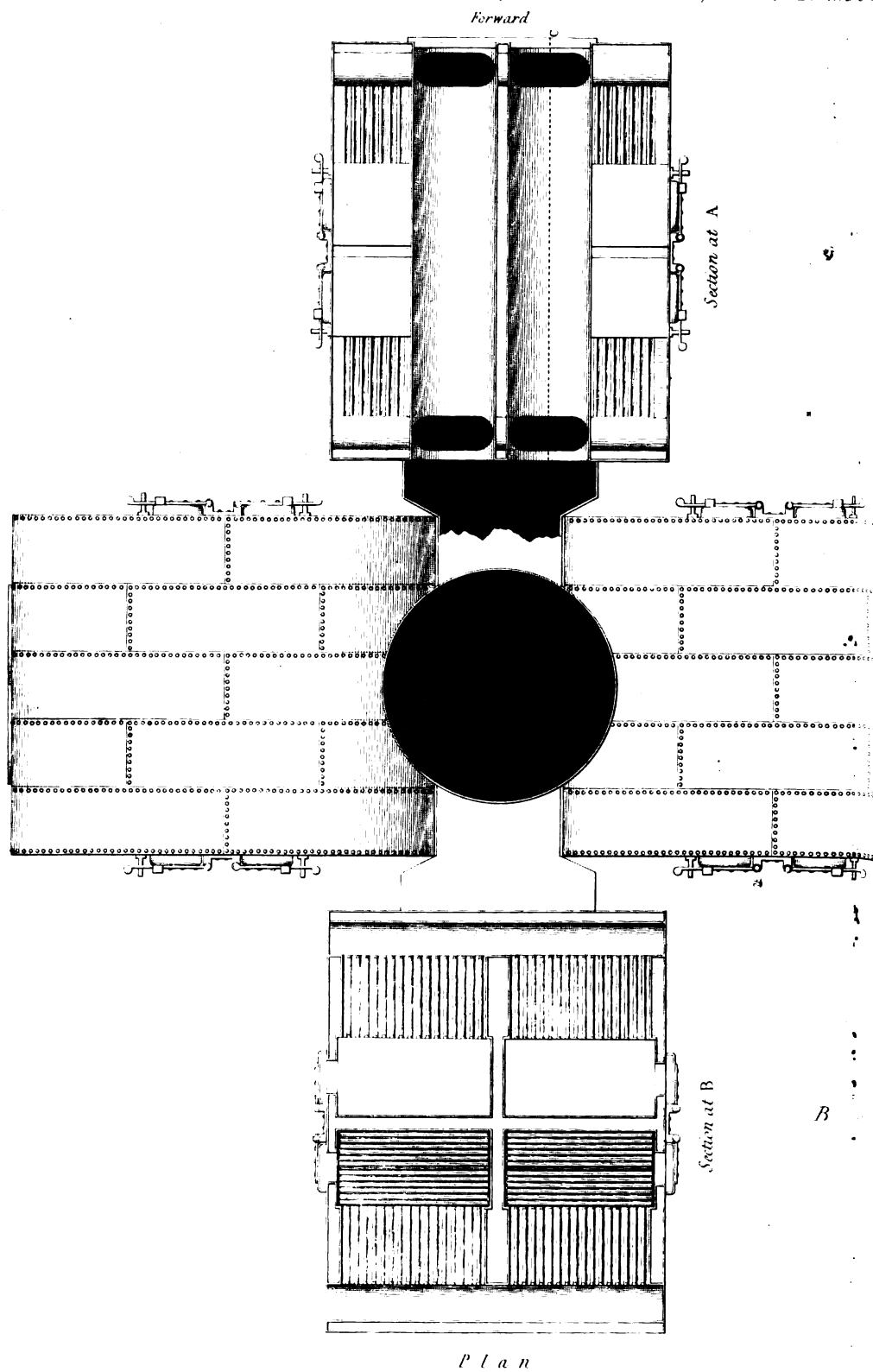
ARRANGED BY R & C L. SCHUYLER, C.E.





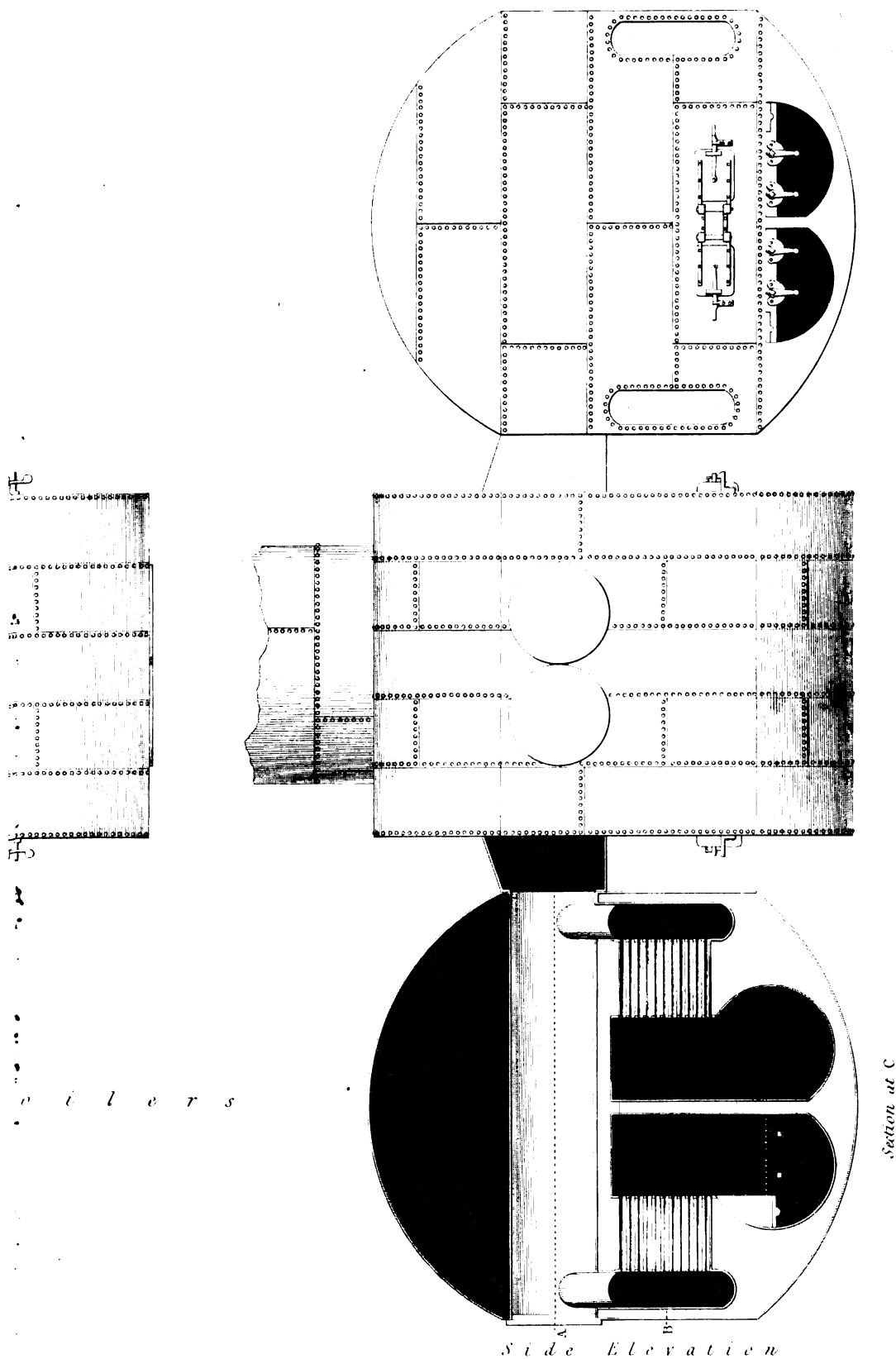
ENGINES OF THE STEAM

ARRANGED BY R & G L



J. Bellamy del.

London Published by John Watts & Co.



J. W. Levy, Engr.

HINTS

ON SOME

IMPROVEMENTS OF THE STEAM-ENGINE.

BY JOSEPH GILL.

THE following remarks on the result of numerous working experiments of the steam-engine, are submitted to the scientific public in the hope that the inquiry may lead to useful results.

The power of a steam-engine, as deduced from theory, is in direct proportion to the transmission of heat from the boiler. The medium of transmission is steam, and as the steam must flow from the boiler to the cylinder through contracted tubes, and tortuous passages, it often undergoes a considerable change of temperature and density in its transit, besides subsequent modifications in the cylinder. In air, and permanent gases, the bulk is inversely as the pressure. When steam is subjected to pressure, a uniform temperature being preserved, its elasticity is partially overcome, a portion of it is condensed into water, and the remainder will occupy a space proportionately smaller as compared with a permanent gas under similar circumstances.

When a vessel containing steam generated under a given pressure is exposed to any cooling influence, the caloric which maintains the elasticity of the steam will escape with a velocity depending on its temperature and the quality of the surrounding medium; and under a constant pressure, any decrease of temperature must cause a partial condensation of the steam, and a corresponding diminution of its volume.

The particles of a homogeneous gas confined in a tube of uniform diameter, will generally retain their relative positions even during regular motion, or gradual contraction or expansion of volume, providing they are free from disturbing eddies or

ENG. V.

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currents. We may assume that such is also the case with steam when no condensation accompanies the change of volume.

If a horizontal tube communicating with a steam-boiler at one end, the opposite extremity being closed, be filled with steam from the boiler, the loss of heat from radiation and the contact of the air, must cause a certain degree of condensation of the steam; and this condensation will be nearly uniform throughout the entire length of the tube. If an aperture is made in the closed end of the tube, so as to allow an escape of steam, a certain degree of motion will take place in the steam inclosed in the tube, and the quantity of condensation will become different at several parts of its length. If, as assumed above, each particle of steam retains its relative position in its transit through the tube, the condensation must be greater as the distance from the boiler increases. Consequently, the temperature of the steam gradually decreases from the source of supply to the farther extremity of the tube; but the pressure in the boiler being constant, the elasticity of the steam will be uniform, or nearly so, throughout the whole extent of the tube.

From the foregoing remarks we may deduce the following conclusions:

1. That when steam at a constant temperature is subjected to a pressure greater than that under which it was formed, a certain portion is condensed into water, and the remainder assumes a bulk and elasticity proportionate to the pressure.
2. That when steam under a constant pressure undergoes a decrease of temperature, a corresponding condensation and diminution of volume take place.
3. That steam in motion through a tube exposed to a uniform cooling medium, undergoes a progressive decrease of temperature as the distance traversed by it increases; and consequently, that the temperature varies at different parts of the tube.
4. That the pressure being constant, the elasticity of the steam is nearly uniform throughout the tube, notwithstanding the variation of temperature.

In boilers of large capacity compared to their power, the generation of steam is so regular, that no condensation can take place from any sudden accession of pressure on the steam in its passage to the cylinder, and this source of condensation can exist only where the steam is subject to sudden variations of temperature and pressure. But in all engines, a certain degree of condensation must take place from loss of heat by radiation and contact of the atmosphere, when the steam contains as much water as it is capable of holding at its temperature.

In endeavouring to ascertain the amount of loss from cooling in the pipes and cylinders of steam-engines, it is requisite to distinguish between the simple loss of

heat, and the consequent loss of elastic force in the steam. In most instances, the steam-pipes are of uniform diameter, and free from contractions between the boiler and the valve boxes. It is allowed that the steam, till it has passed the narrowest part of the passages, will have the same density as in the boiler. (Tredgold on the Steam-Engine, Art. 140^a.) The narrowest part of the passages is generally adjoining the cylinder, and since it is found by experiment that the elasticity of the steam in the cylinder is often considerably less than that in the boiler, this loss of tension must be attributed chiefly to the obstruction offered to the free motion of the steam by valves and contracted angular passages, to cooling in the cylinder itself, or to a combination of both these causes.

Tredgold, after giving, in Art. 145, a formula for ascertaining the loss of force by cooling, states as follows: "In applying this formula to find the loss of heat, no other circumstances are to be considered; but in its application to determine the loss of elastic force, there is a most important point to which I would most particularly direct the attention of the manufacturers of engines. It is the degree to which the temperature of the steam is reduced by passing through the pipe. It is said to be frequently so much as would reduce its temperature below 212° ; when this is the case, we know that part of the steam must become water, and the rest of it become of the force equivalent to a temperature of 212° , and therefore all the excess of force which was generated in the boiler, would be destroyed by cooling in the passage to the engine."

The same author, in Art. 148, adds, that "in steam-boat engines, when the steam has to pass round the cylinders, the force in the cylinder is stated, from observation, not to exceed 28 inches when the force in the boiler is about 36 inches."

Mr. Alexander Gordon, in his Treatise on Locomotion, mentions an instance of a high-pressure engine, in which the steam in the boiler was of a pressure of 55 pounds per square inch, while the steam at the piston, after traversing a pipe 60 feet long, with seven angular bends, was 49 pounds per inch; and the author adds that "this loss of six pounds is to be accounted for mainly by the steam having lost its heat in travelling so far."

Many other instances might be adduced, in all of which it is supposed that the loss of tension in the steam at the piston, is chiefly caused by the loss of heat in its transit through the steam-pipe and passages.

It seems probable, however, that the loss of elasticity in the steam is chiefly attributable to the obstruction of the valves and passages, and to cooling in the cylinder itself; for if the steam be supposed to suffer no reduction of velocity from friction

^a Tredgold on the Steam-Engine; the much improved edition in 2 vols., published by Mr. Weale.

and other retarding forces in its passage to the piston, the cylinder would be supplied with steam of a temperature lower than that in the boiler, by the quantity of heat lost in the passage, but still of a tension very nearly equal to that of the steam in the boiler, since the usual velocity of the steam in the pipe is only about one seventeenth of the velocity with which steam of common atmospheric pressure would flow into a vacuum.

The condensation which takes place in a long steam-pipe causes a considerable loss of fuel, but when the supply of steam is abundant, the power of the engine should not be much affected by this cause, provided the water resulting from the condensed steam returned directly to the boiler, and the cylinder were supplied with dry steam. But such is not generally the case, as in most instances the water formed in the pipes is carried on with the steam into the cylinder.

When boilers of small capacity, compared with their fire surface, are made to generate steam rapidly, the ebullition is often so violent as to cause a quantity of the boiling water to rise in a kind of spray, which is carried over with the steam into the cylinders. This circumstance, well known under the technical term of priming, is allowed to be highly detrimental to the action of the engine. The direct loss of heat from this source is evident at once, but it appears to me, both from description and experiment, that the consequent loss of effect in the working of the engine is greater than we might be led to anticipate from the mere mechanical effects of a little water in the passages and cylinder.

From the result of several experiments, as well as from theory, I am led to infer that the presence of water in the cylinder, whether derived from condensation or priming, causes a very considerable loss of heat, and consequently of useful effect in the cylinder, besides mechanically retarding the motion of the steam in the passages, and increasing the friction of the piston.

During the motion of the piston, the water formed by condensation in the pipe, or carried over by priming, will enter the cylinder with the steam. The mechanical effects of this water in the passages and on the piston, are of secondary importance, and I would first direct attention to the loss of heat which its presence may cause in the cylinder. During the downward stroke in a vertical cylinder, the water which enters it with the steam may be supposed to settle down on the piston. As the temperature of the cylinder is generally lower than that of the steam which enters it, a certain degree of condensation will take place in the cylinder itself, and the resulting water will adhere in minute drops to the interior surfaces, or perhaps partially trickle down the sides and unite with that already on the piston. So far the loss of heat will be the quantity which had been expended in converting into steam the water re-

sulting from condensation, and in raising to the boiling point the temperature of the water carried over by priming. If the hot water which exists in the cylinder from either or both of these sources, were to pass on to the condenser in a liquid state, no further loss of heat would ensue from this source; but the moment the piston reaches the extremity of its stroke, and the passage to the condenser is opened from the top of the cylinder, the water which it contains is relieved from the pressure of the steam, and part of it instantly assumes the form of vapour, while the temperature of the remainder sinks to a point regulated by the degree of rarefaction which exists in the condenser. This is its boiling point under the diminished pressure, which, in common engines, may be taken at about 110° ; and as with low-pressure steam the heat of the cylinder will not be generally less than 212° , this excess of temperature will cause a rapid conversion into steam of any water which may remain in the exhausted cylinder.

The heat of steam is a constant quantity, whatever may be the pressure under which it is generated, consequently the formation of a given quantity of vapour in the cylinder must deprive it of a portion of caloric equal to the heat of conversion into steam of an equivalent quantity of boiling water. This reduced temperature of the cylinder causes a corresponding condensation of the steam with which it is filled at the succeeding stroke, and so on until an equilibrium is established. The cylinder will now have acquired a constant temperature, which, independent of exterior causes of cooling, will be considerably lower than that of the steam in the boiler.

Here, then, is a source of loss which none of the precautions usually employed seem adequate to counteract. When the quantity of water which enters the cylinder, whether from condensation or priming, is considerable, we should only increase the evil by surrounding the cylinder with a steam case, since the evaporation will be more rapid and copious in proportion to the increased temperature of the cylinder; and hence the cause of a loss of heat in the belts and jackets of cylinders, far beyond what ought to take place from external sources only.

In Mr. Dinnen's interesting paper on marine boilers, (see Tredgold on the Steam-Engine,) a striking instance of loss of heat from cylinders is given. "In the African, the cylinders are about 5 feet 3 inches distant from the boilers; there are no hatches *immediately* over them, and the short steam-pipes are covered with fearnought, &c. The quantity of distilled water produced from the belts of 50 square feet surface which girt the cylinders, (there are no jackets surrounding them,) in the Mediterranean, was constantly about 270 gallons in 24 hours; that is, a quantity of fuel was lost by radiation from the belts of the cylinders, in 24 hours, equal to that which would raise 270 gallons of water at a boiling temperature into steam."

From several experiments made by me on the condensation of vapours, I found that when steam of the constant temperature of 215° was passed through tubes of tin plate painted black externally, a surface of about 200 square feet exposed to the air, condensed one cubic foot of water in an hour, when the thermometer stood at 64° . In the case of the African, we cannot suppose that less than 250 square feet of surface would condense one cubic foot of water in an hour, and on this supposition, the area of the belts being 50 square feet, the condensation should be about 0.2 cubic foot per hour, or about five cubic feet in 24 hours. The actual quantity was 44 cubic feet, (270 gallons,) and Mr. Dinnen adds, that "the loss here recorded is rather under than overrated." Thus we have the proportion of nearly eight ninths of the water produced unaccounted for by radiation alone.

I will now proceed to detail some experiments lately made by me, as the results will throw additional light on the subject. These experiments were tried with a small engine, constructed under my own inspection, working expansively with two cylinders, the smaller one being of polished brass, sixty square inches area, and fourteen inches stroke, with one inch clearance at each end. The steam passages are opened and closed by a common slide valve, and the steam-pipe of copper, sixty-four feet long, is exposed to the air of the boiler-house and engine-room. After working the small cylinder, the steam passes into a cast iron cylinder, 115 inches area and 30 inches stroke, where it undergoes a proportionate expansion, and then passes into a common condenser with a jet of cold water. While the steam in the boiler was kept at a constant pressure of ten inches of mercury, about 226° of temperature, a uniform velocity of the engine, at the rate of forty-five strokes per minute, was maintained by adjusting the resistance or load of the engine, the throttle valve being entirely open; and the supply of water to the condensing cistern was so regulated as exactly to supply the jet. When the water in the cistern acquired a constant temperature, the warm water discharged by the air pump, during a stated period, was carefully measured, and its temperature ascertained.

The temperature of the water supplied to the condensing cistern, was 68° , and the air-pump discharged in one minute, or forty-five strokes, 2520 cubic inches of water at 112° , of which about 2415 inches are injection water, and 105 inches condensed steam. To raise the temperature of 2415 cubic inches of water from 68° to 112° , or 44 degrees, the condensation of about 105 cubic inches of water, converted into steam at 214° , is required. Therefore a quantity of steam, equal to what would be produced from 105 cubic inches of water, must have passed through the engine in one minute, besides what is required to supply the loss of heat by radiation from both the cylinders.

The pressure of the steam at the piston was seven inches of mercury, equal to 37 inches against a vacuum, and the temperature, as nearly as could be ascertained, was about 214°. To find the number of volumes into which water will expand when converted into steam of any given elastic force and temperature, Tredgold, Art. 121, gives the following rule:—"To 459 add the temperature in degrees, and multiply the sum by 76.5. Divide the product so obtained by the force of the steam in inches of mercury, and the result will be the space in cubic feet the steam of a cubic foot of water will occupy." To apply this to the present case :

$$459 + 214^{\circ} = \frac{673 \times 76.5}{37} = 1392.$$

Or the steam of one volume of water will occupy 1392 volumes at the above temperature and pressure.

Now to ascertain whether the steam which passes through the engine exceeds the quantity which ought to suffice for its regular supply, (supposing no extraordinary loss of heat from the cylinder to take place,) we should find this quantity by calculation.

Thus the cylinder being 60 square inches area, and 16 inches stroke, including the clearance, and the steam passages being 2 inches area by 20 inches long, the entire quantity of steam consumed by one stroke or revolution of the crank will be

$$\begin{array}{rcl} 60 \times 16 & = & 960 \times 2 = 1920 \text{ the cylinder,} \\ \text{and } 20 \times 2 & = & \dots\dots\dots 40 \text{ the passages.} \\ \hline & & \text{Total, } 1960 \text{ cubic inches.} \end{array}$$

And the consumption in one minute will be $1960 \times 45 = 88,200$ cubic inches, and adding one tenth, or 8820 inches, for loss by cooling and leakage, we have a total of 97,020 cubic inches, or about 56 cubic feet, which is the quantity of steam the engine should consume in one minute.

By experiment it was found that about 105 cubic inches of water in the form of steam passed through the engine in a minute, and since each cubic inch of this water should, according to the foregoing calculation, expand into 1392 cubic inches of steam, we have a total of $105 \times 1392 = 146,160$ cubic inches, or about 84 cubic feet, actually consumed in a minute.

The quantity of steam which ought to supply the engine during a period of one minute, was found above to be 56 cubic feet, but the actual consumption exceeds this quantity by one half. We have thus a loss of fifty per cent. unaccounted for, except-

ing by some powerful latent influence in the interior of the cylinder. The above result is the mean of several experiments, and as the piston and valves were carefully proved to be in good condition, we cannot attribute much loss to leakage.

The same experiments were repeated with the larger cylinder detached, the steam passing at once from the small cylinder to the condenser; and the results, after allowing for radiation from the large cylinder, nearly coincided with those of the former experiment. This is of course an extreme case, both on account of the great length of the exposed steam pipe, and the small size of the cylinder; but after the most ample allowance is made for these circumstances, the experiments prove beyond a doubt that the presence of water in the cylinder, from whatever source it may be derived, causes an immense loss of heat.

The following experiment shows that the temperature of the cylinder when in action is considerably lower than that of the steam in the boiler, and the difference cannot wholly be accounted for by radiation or expansion. After the engine had been some time in regular action, with the throttle valve fully open, the steam in the boiler at the temperature of 240° , pressure 22 inches of mercury, the oil in the oil-cup on the cylinder cover indicated a constant temperature of 212° during several minutes. The engine was now stopped at three quarters stroke during the descent of the piston, and the fly-wheel being fixed in this position, the upper steam passage was left fully open, so that the steam, which was carefully maintained at the same temperature in the boiler, was in free communication with the upper part of the interior of the cylinder; in a short time the oil indicated a temperature of 221° . These indications are of course lower than the actual temperatures in the interior of the cylinder, but their relative proportions may be nearly exact.

When water is formed in the cylinder, or is introduced into it with the steam, even in the proportion of half the quantity required to produce the steam for supplying the engine according to the theoretical calculation, it is easy to prove that, when relieved from pressure by the removal of the superincumbent steam, its evaporation should be very rapid. By the foregoing calculation it was found that one cylinder full of steam equal to 960 cubic inches, is produced from about 0.7 cubic inch of water. One half of this quantity, or 0.35 cubic inch, will therefore be the water existing in the cylinder at the termination of a stroke; and supposing that, (during the downward stroke,) the entire quantity settles down on the plane surface of the piston, which is 60 square inches area, the film of liquid will not exceed the $\frac{1}{160}$ th of an inch in thickness, or scarcely more than that of common writing paper. If we imagine such a film of water to exist on a flat metallic surface, at a heat a little below 212° , and that the temperature is suddenly increased to near 312° , the water would fly off in steam almost in-

stantaneously, abstracting from the metal a portion of caloric equal to the heat of its conversion into steam. Similar phenomena take place in the interior of the cylinder: a film of water is deposited on the surface of the piston and cylinder, which are kept by the steam at a temperature we will suppose of 212° , and as long as the steam presses on the liquid, very little evaporation takes place; but the moment the pressure of the steam is removed, on opening the passage to the condenser, the boiling point of the water suddenly becomes about 110° , and as the metal with which it is in contact remains at 212° , there is an almost instantaneous excess of about 100° of temperature above the now reduced boiling point of the liquid, which must cause its immediate evaporation.

When the steam acts expansively, the loss of effect from evaporation in the cylinder should be less than when working at full pressure, since a certain portion of the water from the condensed steam, or perhaps the whole, will be reconverted into vapour as the pressure in the cylinder diminishes by expansion, and this vapour will assist the action of the piston. Also during the return stroke a smaller quantity of water, or perhaps none, will remain to be evaporated, and the loss of heat will be proportionately less.

It is very difficult to estimate correctly the mechanical effects of water in the cylinder, and we can only guess at the probable results. It is well known that when a considerable portion of water is carried over into the cylinder by priming, the motion of the engine is greatly retarded, and this diminution of effect appears to be in part owing to an increase of friction in the piston. We can imagine that water mixed with the steam would retard its progress through the narrow passages, and particularly at angular turnings, but the loss of force from this source cannot be very considerable. If a certain quantity of water is forced by the steam through any existing crevices into the interstices behind the packing of the piston, as soon as the pressure of the steam is removed from its surface the inclosed water acquires an instant tendency to expand into steam; and if the crevices through which the water entered are not sufficiently wide to allow its free escape, the consequence will be that the internal expansion of the water will augment the outward pressure of the packing, and thus cause an increase of friction. The elasticity of the packing must also be affected by the interstices being filled with water, and the whole arrangement probably becomes more stiff and rigid. When the priming is excessive, an accumulation of water may take place in the cylinder; and should the quantity be so great as to impede the progress of the piston towards the termination of the stroke, some serious injury to the machinery is to be apprehended from the incompressible nature of the liquid.

The theory of transmission from the boiler to the cylinder has not hitherto been satisfactorily investigated and explained, and in making experiments on the subject, the preceding remarks will show how essential it is to prove whether the steam is dry; or if otherwise, as is often the case, to ascertain the precise quantity of water which may be mechanically combined with it.

In theory, the consumption of steam is calculated for the exact quantity which ought to supply the cylinder, supposing steam to be subject to the same laws as permanent gases, and to this amount is merely added an approximate allowance for leakage and loss of heat by radiation. The loss from the latter source can be calculated with comparative precision; and if the water produced by this cause passed on to the condenser in a liquid state, we might hope to arrive at accurate results, provided that the boiler furnished dry steam. If we suppose the cylinder to be supplied with dry steam, and that no heat is dissipated by radiation, there will still be a loss of heat in the cylinder, occasioned by the sudden expansion of the steam when the communication with the condenser is opened, since its specific heat diminishes more rapidly than the diminution of its volume, and its capacity for heat becomes greater as its expansion increases. However, as steam receives heat slowly, the loss from this source will probably be of small amount.

To determine the loss from cooling in the pipes and cylinder, we must not only calculate the direct loss of heat from the condensation of a given volume of water, but also the quantity of caloric which must be abstracted from the heated metal of the piston and cylinder to reconvert into steam this water at the boiling point. This will nearly double the quantity deduced from the ordinary calculation of loss from external sources only. But the loss would still be comparatively small if the boilers furnished dry steam. In the case of the African, already quoted, the condensation from the belts alone should have been about 0.2 cubic foot per hour, or about $1\frac{1}{2}$ gallon. If we allow as much more for loss from the exposed cylinder covers, slide casings, and covered steam-pipe, we shall have 0.4 cubic foot per hour, or about 3 gallons. This would be the direct loss from condensation; but, according to the foregoing theory, we should allow about five-sixths of this quantity for its reversion into steam. This allowance should obviously be made, since the heat abstracted from the cylinder by the evaporation must be compensated by an equivalent quantity derived from the steam which enters the cylinder at the succeeding stroke, (if no steam case is used,) and as the steam cannot lose any of its caloric without undergoing a partial condensation, the consequence must be the formation of a fresh quantity of water, to be again evaporated with similar results. But when steam is applied externally, about three fourths of this condensation may be supposed to take place in the steam-case, or in this instance less

than 2 gallons. This quantity, added to the $1\frac{1}{2}$ gallon calculated for direct loss from the belts by radiation, gives a total of $3\frac{1}{2}$ gallons per hour. But the actual quantity condensed was $11\frac{1}{4}$ gallons per hour, and we have thus $7\frac{3}{4}$, or more than two thirds of the whole quantity, unaccounted for, unless we suppose a certain quantity of water to be mechanically suspended in the steam.

It is generally stated by writers on the steam-engine, that the evaporation of one cubic foot of water produces one horse power in a low-pressure engine working without expansion, and that nine pounds of good coals will evaporate this quantity. The water for supplying the boiler, and the injection water, are also calculated on this basis, which is in accordance with theory, if no internal loss of heat is supposed to take place in the cylinder.

In practice, however, it is often found that the consumption of fuel greatly exceeds the theoretical estimate, and Dr. Lardner, in his *Treatise on the Steam Engine*, states, that “throughout the manufacturing districts in the North of England; the average consumption of coals under land boilers of all powers above the very smallest class is at the rate of fifteen pounds of coals per horse power per hour.”

Brunton, in his *Compendium of Mechanics*, states that each horse power requires nearly $7\frac{1}{2}$ gallons of cold water per minute for condensing, and he gives five gallons as a minimum. Six gallons is the quantity generally allowed in practice, but even five gallons per minute would be about 40 cubic feet per hour, and if we suppose that one cubic foot per hour furnishes the steam for one horse power, the injection water will be 40 times the quantity which produces the steam, while it is found from theory that 24 times the quantity is sufficient to condense at 100. (See Tredgold, Art. 284.) Brunton adds, that the consumption of coals per hour for one horse power is from 13 to 20 pounds, according to the strength of the fuel, and the manner in which the furnace is fed. The quantity of fuel consumed in a given time will not always give even a fair approximation to the actual quantity of steam produced, as the state of the boiler and flues, and the manner of feeding the furnace, must greatly influence the result. Neither will the quantity of water required to supply the boiler be always a correct criterion by which to estimate the real amount of evaporation, as the result may be affected by priming. In condensing engines, after calculating the probable loss from radiation and leakage, we can form a close approximation to the actual quantity of heat transmitted from the boiler, by ascertaining the quantity and temperature of the water discharged by the air pump; and as the power of a good engine should be in direct proportion to the transmission of heat, we thus obtain a correct standard with which to compare the actual effect of the engine.

I am led to believe, from various circumstances, that water is often mechanically

suspended in steam when its presence is not suspected. Any method of vaporization on the principle of the ingenious arrangement of Howard, would obviate this inconvenience, but in common hands the production of steam might be subject to sudden inequalities. In common boilers the heated gases from the flues might, before entering the chimney, be made to act on the steam, either through the medium of a steam-chamber before entering the cylinder, as in Howard's plan, or, what would be better, a system of small tubes through which the steam might pass immediately on leaving the boiler. By this means the steam would not only absorb more heat, but it would also acquire a high temperature with a relatively low density or pressure. Any water which might be carried over by priming would, if not in excess, by this means be converted into vapour, and the expanded steam might suffer a considerable reduction of temperature before any condensation would take place. This circumstance would in general be highly favourable to the effective working of engines, as the formation of water in the pipes and cylinders cannot be entirely prevented by other means, and it has been shown that the presence of water in the cylinder must cause a great loss of heat. In the most improved locomotive engines, the cylinders are placed in the smoke box, which is also traversed by the steam-pipe, and the advantage of the arrangement is obvious as far as the increased temperature and expansion of the steam are concerned. Precautions are also taken to prevent the admixture of water with the steam as it leaves the boiler; a similar arrangement is sometimes employed in common stationary boilers, and it ought to be adopted in all cases where it is probable that the boiler does not furnish dry steam.

It will, I think, be evident from the foregoing remarks, that, as engines are usually constructed, we cannot expect to obtain the full effect of steam, unless, after its formation, it is heated out of contact with water so as to acquire a high temperature with a relatively low density or pressure. The application in practice is easy, on the principle that when steam is confined in a tube, its temperature may be different at different parts of the tube, and yet the pressure be uniform throughout its entire length. All that is required is to increase the temperature of the steam after it leaves the boiler, and one simple mode of effecting this would be, as suggested above, to cause the heated gases, before entering the chimney, to act on the steam through the medium of any convenient arrangement of metallic surfaces. The steam might also be made to pass directly through a heated liquid, whose boiling point is at a high temperature, and the heat of which can be easily regulated. I have tried some experiments on this principle, which promise to lead to useful results, and I would direct the attention of engineers to this suggestion. Marine engines consume less fuel in proportion to their power than ordinary fixed engines. This in

part results from the boilers, but may not some economy result from the circumstance that the steam of salt water has a higher temperature than that from fresh water when both are of equal pressure?

In low pressure engines, the power is produced chiefly by condensation, and the useful effect should be directly as the rarefaction in the condenser. Only two methods of condensation have been used, viz., by the direct contact of cold water by injection, or by the contact of metallic surfaces kept at a low temperature by means of cold water or otherwise. The former method has been generally used with very little improvement since its first accidental discovery in the old atmospheric engine, while the latter, after having been unsuccessfully tried by Watt and others, has only very lately been effectively used on the large scale in Mr. Samuel Hall's arrangement of small tubes surrounded with cold water.

As water would boil in a vacuum at 80° , it is difficult to effect perfect condensation under reduced pressures, and the condenser gauge in steam-engines seldom indicates a degree of rarefaction beyond 28 inches of mercury.

The common method of injection possesses the advantage of great simplicity of arrangement, but the air introduced with the injection water, and the force required to remove this water, are serious drawbacks; neither by the common mode of construction is the condensation effected with the greatest possible rapidity. On inspecting the indicator cards of engines condensing by injection, it will be generally found that the maximum of rarefaction in the cylinder does not take place till after a certain interval from the moment the passage to the condenser is opened, and in most instances not until the end of the stroke. For example, in the action of a cylinder of six feet stroke working at full pressure, the maximum pressure on the piston from vacuum being $12\frac{1}{4}$ pounds per square inch, it may be found that during each foot of the stroke the mean pressure will be as follows:

1st foot of stroke	7	pounds per square inch mean pressure.
2nd	"	$9\frac{3}{4}$ "
3rd	"	11 "
4th	"	$11\frac{3}{4}$ "
5th	"	12 "
6th	"	$12\frac{1}{4}$ "
		<hr/>
		$63\frac{3}{4}$
		<hr/>
		6
		$\frac{63\frac{3}{4}}{6} = 10.62$ pounds per square inch, which is the mean

pressure from vacuum throughout the whole stroke. But the maximum is 12.25

pounds per inch, therefore there is a loss of 1.63 pound per square inch on the piston during the entire stroke. This loss is occasioned wholly by the time required to condense the steam, for if it were condensed as fast as it could enter the condenser, or if the condenser were a vacuum space of infinite capacity, the steam, after allowing for its probable retardation in the eduction pipe, should at the first instant rush out of the cylinder with a velocity of about 1100 feet per second, and its mean velocity would be about 550 feet per second. At this rate, the exhaustion of a six feet cylinder would be almost complete in little more than a quarter of a second, and when there is a slight lead on the valves, or their motion anticipates that of the piston, all the steam would have passed into the condenser before the piston commenced its return.

From an estimate of the air and uncondensed vapour supposed to exist in the condensers of engines, Tredgold gives the proportion of the air-pump as one eighth of the contents of the cylinder, the condenser being of equal capacity; and he calculates the power required to work the air-pump at about one twentieth of the power of the engine.

The condensers and air-pumps of engines are often made larger than the proportions deduced from theory. Whatever may be the size of the pump, as long as the quantities of the air, vapour, and water drawn from the condenser are constant, the same power will work it, modified only by friction; and the friction does not increase directly as the area. One very obvious advantage of a large condenser is, that the exhaustion of the cylinder during the first portion of the stroke will be more rapid as the capacity of the condenser is greater, and it is during this portion of the stroke that the resistance of the waste steam is the greatest.

In Hall's condenser, as fitted in the Wilberforce, described in the explanation of plates 51 to 54 of Tredgold's Steam Engine, the capacity of the tubes alone is about one fourth of the contents of the cylinder, and the total capacity of the condenser and passages is not less than half the capacity of the cylinder. The steam had thus greater freedom of expansion, while the immense surface of upwards of 2400 square feet of cold metal presented by the condenser must cause very rapid condensation. If the common injecting condenser were made equally capacious, and the jet so contrived that the water would present a surface as extensive as that of the tubes, we might expect the exhaustion to be equally rapid. The indicator diagrams showing the performance of the engines of the Wilberforce, offer a striking example of the advantages of rapid condensation.

Tredgold, in Art. 352, on the Steam Engine, proposes to reduce the power expended on the air-pump to one half, on the supposition that a pump half the size would be as effective as the present construction, if we could condense in the

pump itself. The idea is obviously erroneous, for even supposing such a small pump would be equally effective, the same power would still be required to withdraw the contents of the condenser. Thus we should only diminish the friction about one fourth, and supposing the estimate given in Art. 355. to be near the truth, the consequent saving of force would be only about one seventh. In the application of this idea, as proposed in Art. 400, it will be seen that the solid piston of the air-pump is at the top of its stroke when the communication is opened between the cylinder and the condenser, and as by this arrangement the waste steam has very little space for expansion, its egress from the cylinder must be regulated by the rate of condensation effected by the injection jet. The exhaustion will consequently be slow, and the piston will encounter a considerable resistance from the uncondensed steam during the first part of its stroke.

From the results of many experiments, I am inclined to believe that an increase of power is gained by increasing the capacity of the condenser and air-pump, as long as the air-pump does not exceed one fourth and the condenser three fourths of the contents of the cylinder. To insure rapid condensation it is essential that the shower of injection water should present an extensive surface; it must therefore be subdivided into minute drops, and this important arrangement is more easily effected in a large condenser.

The admission of injection water is easily regulated so as uniformly to maintain a given temperature in the condenser by any suitable thermostatic arrangement placed in the hot well, and acting on a cock or valve in the supply pipe.

In some experiments, made with a view of ascertaining the possibility of condensing in the cylinder of an atmospheric engine without much loss of heat, I found that by minutely subdividing the injection water, and extending the jet so as to occupy nearly the whole interior of the cylinder, a rapid condensation could be effected when the steam was not of more than common atmospheric pressure. The cylinder was lined internally with wood so prepared as to be impermeable to steam and water, and having at the same time a very low power of imbibing or conducting heat.

MARSALA, SICILY,
Sept. 1st, 1843.

NOTICES
OF
WORKS ON ENGINEERING,

PUBLISHED IN THE PRECEDING QUARTER.

PAPERS on Subjects connected with the duties of the CORPS of ROYAL ENGINEERS,
Vol. 6, in 4to, which comprises the following.

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| Notes on the Field Equipment of the Engineer Department with the Bengal portion of the Army of the Indus. By Lieutenant H. M. Durand, Bengal Engineers. | Description of the Saw Mills and Machinery for Raising Timber, in Chatham Dock-yard. By Mr. Dempsey. |
| Note on the Defensive Works in Jellalabad, prepared by order of Major-General Sir Robert Sale, K.C.B. | Description of a Saw Mill used in America. |
| Notes on Acre and some of the Coast Defences of Syria: with Plates, &c. By Lieut.-Col. Alderson, Royal Engineers. | Description of a Wooden Swing Bridge, erected over the Grenville Canal, Canada. |
| Report of Experiments in Blowing in Gates, made at Quebec on the 11th and 13th July, 1840, by order of Lieut.-Colonel Oldfield, K.H., Commanding Royal Engineer in the Canadas. | On the System of combining Mechanical Ventilation with warming by Steam Heat, as adapted to Public Buildings. By Mr. Spencer. |
| Memoranda relative to the Reconstruction of certain portions of the Admiralty Sea Wall at Haslar Beach, Portsmouth. By Lieut. Beatson, Royal Engineers. | The Patent American Steam Pile-Driving Machines. By Mr. G. Spencer. |
| Practical Essay on the Strength of Cast Iron Beams, Girders, and Columns; in which the principles of calculation are exhibited in a plain and popular manner. By William Turnbull. | The American Railroads formed on a Foundation of Piles. |
| Hydraulic Press for proving Girders. | Description to accompany the Plans of the Method of Raising Buildings by Screws, in Canada and the United States. By T. Hounslow, F.W., R.E.D. |
| | Account of the Demolition and Removal by Blasting, of a Portion of the Round Down Cliff, near Dover, in January, 1843. By Lieut. Hutchinson, Royal Engineers. |
| | Report of Experiments made with a Shot Furnace at Malta. |

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Description of some Iron Roofs erected at different places within the last few years. By Captain Denison, Royal Engineers.

On the use of Fascines in forming Foundations to Buildings. By Colonel Lewis, Royal Engineers.

Detail of some Experiments carried on in Her Majesty's Dock-yard, Woolwich, for the purpose of ascertaining the Resistance of Brickwork under various conditions.

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PECLET TRAITE du CHALEUR, 2 vols. 4to, and atlas folio of plates; price, in Paris, 65 francs, but in Belgium there exists a disreputable system of reprinting valuable copyright books. Avanzi, of Liège, advertises this work to be shortly published at 25 francs, an incredible low price for so extensive a work; to counteract in some measure Avanzi's advertisement, the French agents in Liège were offering the genuine edition at 35 francs; this price only produces a profit of 2 francs upon each copy sold. This is a lamentable state of things; it will tend to debase literature, and drive into other trades the vast capital necessary to be employed in publishing speculations.

The principle upon which our international copyright law was passed some few years ago ought to be the subject of a special treaty between Great Britain and France.

MEMOIRS of the LITERARY and PHILOSOPHICAL SOCIETY of MANCHESTER, Second Edition, Vol. 7, Part 1, in 8vo.

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| On the Roman Military Road between Manchester and Ribchester, by John Just, Esq. | A Sketch of the Life and Character of John E. Bowman, Esq., F.L.S. and G.S., by the Rev. J. J. Taylor, B.A. |
| On the Use and Origin of Surnames, by the Rev. Wm. Jones. | |

PORTEFEUILLE de l'INGENIEUR des CHEMINS de FER, par AUG. PERDONNET, et C. POLONCEAU. Text in 8vo, and plates in atlas folio, livraisons 1, 2, 3, 4, 5, and 6, 10s. each. *Paris*.

TEMPLETON'S ENGINEER'S POCKET BOOK, for the year 1844. Contents:—Numerous Problems, Rules, and Tables, deduced from theoretical principles, practical observations, and recent well-approved experiments on Materials of Construction, Machinery, Friction, Water Wheels, Steam Engines, &c., &c., together with an ALMANACK, containing, besides the usual matter connected with the year, a variety of Popular Statistical Information, and a Complete Diary for Cash Accounts, Memoranda, &c.

This new Annual Work of Mr. TEMPLETON has been in preparation by that gentleman for some considerable time; he has selected such matters and condensed in form all that is required by the daily practical engineer in the several branches of his Art. It is bound in Morocco with a tuck for the pocket.

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JOURNALS.

THE CIVIL ENGINEER and ARCHITECT'S JOURNAL, July, August, and September, comprising the last quarter, containing several plates, and a great many interesting subjects of novelty, principally in Civil and Mechanical Engineering, with some few papers on Architecture.

THE ARCHITECT, ENGINEER, and SURVEYOR, or London Monthly Journal of Engineering and the Practical Sciences, and of Architecture and the Fine Arts, (July, August, and September,) with several plates, comprising the last quarter.

THE ARTISAN, a Monthly Journal of the Operative Arts, (July, August, and September,) with several plates, comprising the last quarter.

TAYLOR'S SCIENTIFIC MEMOIRS, Part 7, in 8vo.

JOURNAL of the FRANKLIN INSTITUTE, 8vo. Received the Parts for July and August, from New York.

ON SETTING OUT THE WIDTHS OF GROUND REQUIRED

FOR THE WORKS OF A

RAILWAY OR CANAL,

ETC.,

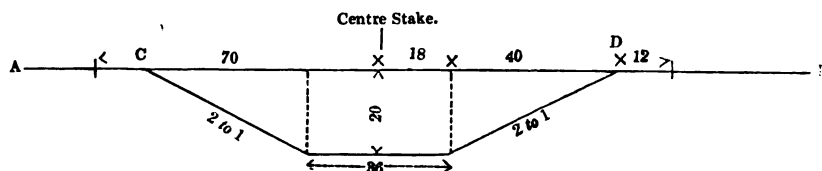
DEPENDING UPON THE DEPTH OF CUTTING OR HEIGHT OF EMBANKMENT, AND THE TRANSVERSE
SLOPE OF THE NATURAL SURFACE.

BY FREDERICK WALTER SIMMS, F.G.S., M.Inst.C.E.

WHEN the natural surface of the ground, both longitudinally and transversely, is upon the same level as that of the intended works, the process of setting and staking out the widths is very simple. Let us take, for example, the case of a railway, the base or bottom width of which, when prepared for the reception of the ballasting and permanent way, is to be 36 feet; the ratio of the inclination, or batter, of the slopes to the heights, both in the cuttings and the embankments, to be 2 to 1; beyond which, or at the outward edge, a slip of land 12 feet wide is to be taken on each side of the railway for the fences, &c. First, the centre line must be staked out and carefully levelled; it is customary to drive a stake about 2 feet long, and about $1\frac{1}{2}$ inches square, into the ground at each chain's length, their tops to be upon the fair level of the natural surface, thus affording good stations for the levelling staves to be held upon; the relative level of each stake being then very accurately determined with respect to some given datum, they become so many zero points for reference in the subsequent operations. From each of the centre stakes a line must be set out on both sides, and at right angles to the centre line, or at right angles to a tangent to the centre line at that point, if the centre line be curved; upon these transverse lines the required widths of land must be set out. Now, if the ground at any of the centre stakes is upon the same level as the intended base of the railway, nothing more will

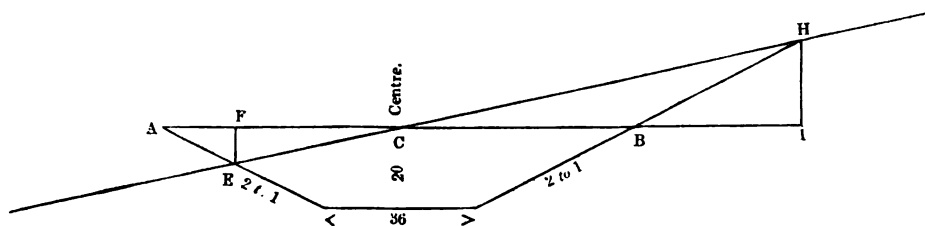
be required than to measure on each transverse line and in both directions from the centre stake one half the required width, which, in our supposed case, is 18 feet for the half width of the railway, and 12 feet for the fences, in all 30 feet on each side of the centre. But when, as it most always happens, the ground is not on the proposed level of the railway, the operation is not quite so simple; and if in addition thereto the ground slopes sidewise or at right angles to the general direction of the line, the business is still more complicated, and requires some skill and care to do the work correctly. The method of doing this is our business to explain.

The next most simple case to the above is when the cross section of the ground is horizontal, be the depth of cutting or height of embankment what it may.



This is shown in the above diagram, which represents a cross section of a 20 feet cutting with slopes of two horizontal to one perpendicular. The horizontal line AB at right angles to the centre line represents the natural surface of the ground. Under these circumstances it will readily be seen that the half width of the cutting, or the distance from the centre to the edge of the slopes c and d, equals the half width of the base (18) added to the batter of the sloping sides (40), and including the 12 feet for the fences, the total half width of land required for the purposes of such railway would be $18 + 40 + 12 = 70$ feet, and consequently the whole required width to be so appropriated and fenced in for a 20 feet cutting or embankment, when the ground does not slope sidewise, would be 140 feet.

The next and more complicated, and also the most frequently occurring case is, when the cross section of the natural surface is not horizontal, as shown in the annexed diagram, which also represents a cutting of 20 feet.



Let the line AB represent a horizontal line passing through the centre line c of the railway, which, if it coincided with the surface of the ground, would give

AC and CB (each half width) 70 feet, as in the former example, the depth of cutting and the slopes being assumed the same.

Let the line EH represent the natural surface of the ground upon this transverse section; it will readily be perceived that the real half width CE (on the left of the diagram) is much shorter than the horizontal or computed half width AC, because the ground-line is depressed on that side of the centre; likewise the half width CH on the other side of the centre is greater than the said horizontal or computed half width, because the ground is there elevated above the horizontal line AB passing through the centre. To determine *exactly* the distances CE and CH in actual operations in the field would be attended with some difficulty and consume much time; but the following method, which at the same time that it gives a sufficiently correct approximation in practice, is also a very expeditious one.

Let us suppose that the point E or distance CE be known, and that with a spirit level we determine the difference of level between the points C and E, this difference is represented by the line EF, which suppose to be one foot; now we have a small right angled triangle AEF, of which EF is determined, being the difference of level (one foot), and the slope or ratio of AF to EF also given, (2 to 1,) therefore the side AF is known (2 feet), which subtracted from the computed half width AC, leaves FC approximately equal to EC, the required half width, sufficiently exact for all practical purposes, where the cross section of the ground does not differ materially from a horizontal line.

We have been supposing that the point E is known, whereas that point is the object of our search; in practice, therefore, we proceed thus:—take the computed half width, and if the ground is *depressed*, let a levelling staff be held somewhat *nearer* the point C than the said computed half width, for a first approximation to the point E; then determine the *difference of level* between this assumed point and the centre point C, *multiply this difference of level by the ratio of the slopes*, (which doubles it when the slope is 2 to 1,) and *subtract* the result from the computed half width, which gives a more correct approximation to the point E; now hold the staff at this *new point* and find the difference of level as before, again multiply by the ratio of the slopes, and deduct the result from the computed half width, which second result will in most cases be sufficiently near the real half width for a *depressed* line for all practical purposes.

EXAMPLE.—Central height (or depth of cutting), 20 feet, slopes 2 to 1, base 36 feet, the computed half width was therefore 58 feet; the ground being depressed, we estimated that the point E might fall short of the computed half width, 2 feet; we therefore directed a levelling staff to be held at 56 feet from the centre line (or

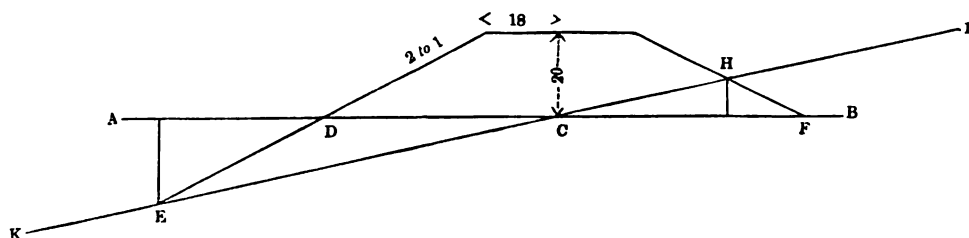
stake) c , at which point another staff was held, and by means of a spirit level set up at a convenient distance, we found the difference of level between these points to be 0.87 feet, which multiplied by the ratio of the slopes 2 to 1, gave 1.74 feet to be subtracted from the computed half width 58 feet, leaving 56.26 feet for a first approximation to the half-width ce , (see last diagram.) Now upon removing the staff to this new point, the difference of level was again taken, (or rather we should say that the staff was again read off, as the level had not been disturbed,) and found to be 0.91 feet, which also multiplied by the ratio of the slopes (2 to 1), gave 1.82 feet to be subtracted from 58 feet, leaving 56.18 for the second approximation, and which was adopted as the correct half width for the depressed side of the centre; indeed, in such a case as is above given, where the ground is so nearly horizontal, the first approximation (taken by a person after a little practice) may be assumed as the correct result, for in the above example it differed but .08 from the second determination, and if it had been taken a third time, it could not have been more accurate as far as practice is concerned; this, however, is not the case where the inclination or slope of the ground is considerable, for then (if this method be followed) several approximations will be necessary to bring the result within admissible limits.

When the ground is *elevated* above the horizontal line, as shown on the right hand of the diagram, the mode of procedure will somewhat differ; thus, instead of holding the staff and finding the difference of level at a *less distance* than the computed half width, it must be held at a *greater distance* to obtain the point h by approximation, the difference of level between that point and the centre point c being equal to hi , and multiplied by the ratio of the slopes, will give the distance bi to be added to the computed half width cb , to obtain the half width ch ; this may likewise be repeated to obtain a more correct result as described for the other, or depressed side of the centre c . It will also here be obvious to a person possessing but the smallest share of mathematical knowledge, that this result is not strictly correct, inasmuch as the line ch can never be equal to ci , but for practical purposes it is, as before observed, sufficiently correct. It may not be altogether unnecessary to observe, in this place, that the corrections bi , &c., as shown in the foregoing diagrams, are much exaggerated, being far greater in proportion to the computed half width cb , than ever occurs in ordinary practice, but this has been done to make our explanations more distinct than could otherwise have been done.

The above particulars have been confined to the case of excavations; we must now show in what the process differs when the ground is to be covered with an embankment.

By reversing page 2 we invert the diagram, which then represents an embank-

ment. The rule for finding the half width for an embankment where the transverse section of the ground is horizontal, remains the same as for the cuttings under like circumstances, as may be seen by an inspection of the inverted figure of the first diagram, but upon inverting the second diagram, (which we have represented below,) it will at once be seen that some variation in the process is required. Thus:—



The horizontal line is represented by that marked AB ; CD and CF the computed half widths; CE the required half width on the depressed side, and CH the required half width on the elevated side, the line KL representing the natural surface of the ground. In the case of an excavation, we have shown that the *real* half width is greater on the *elevated* side than the computed half width, and less on the *depressed* side; but it will be seen by the above diagram that for an embankment the *real* half width is *less* on the *elevated* side, and *greater* on the *depressed* side than the said computed half widths; therefore, in determining the approximate place of the point E on the depressed side for an embankment, the staff must be held *further* from the centre than the computed half width, and for the point H on the elevated side, it must be held *nearer* to the centre than the computed half width; and finally, for computing the real half widths from the differences of level between the points E and the centre, and H and the centre; on the *depressed* side the difference of level multiplied by the ratio of the slopes is to be *added* to the computed half width to obtain the point E , and to be *subtracted* from the computed half widths to obtain the point H .

The process above described may appear to the reader a very tedious one; it perhaps is so to read, but a little practice will convince him that it is a very expeditious method, for in most cases one setting up of the level will answer for several stations, and the multiplications by the ratio of the slopes upon such small numbers as mostly occur is easily performed, especially if it be an even number as 2 to 1. The columns of the field book may be arranged as in the following example for making the calculations in the field, or may be abridged to suit a more convenient sized book for the pocket, at the pleasure of the surveyor; indeed, all that can be accomplished in a paper of this kind is to give general rules which can be altered and arranged to suit the convenience of the surveyor, as experience may point out a more suitable mode

of proceeding. The example is taken from an extensive field operation by the writer, and shows the work both for a cutting and an embankment, the change from one to the other, or the tailing out of the cutting, as it is called, being included therein. The slope of the cutting is calculated at $1\frac{1}{2}$ to 1, and that of the embankment at 2 to 1. The width of the railway was 36 feet, consequently half the said width was 18 feet.

EXAMPLE.

No. of Stake.	Depth of Cutting or Embankment.	Computed half width.	Section or Level Readings at right angles to Line.			Difference of Level. + -		Difference of Level, \times ratio of Slope. + -		Required half width for edge of Cutting or foot of Embankment.	
			South.	Centre.	North.	South.	North.	South.	North.	South.	North.
EMBANKMENT.											
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
285	16.97	51.94	10.90	7.50	3.96	+3.40	-3.54	+6.80	-7.08	58.74	44.86
286	1.43	20.86	7.06	4.74	3.24	+2.32	{ +0.07 -1.50 }	+4.64	+0.11	25.50	20.97
287	2.77	23.54	8.00	5.80	4.26	+2.20	-1.54	+4.40	-3.08	27.94	20.46
288	3.06	24.12	8.82	6.42	5.12	+2.40	-1.30	+4.80	-2.60	28.92	21.52
289	2.01	22.02	7.02	5.13	3.74	+1.89	-1.39	+3.78	-2.78	25.80	19.24
290	1.22	20.44	6.00	4.10	2.76	+1.90	{ +0.12 -1.34 }	+3.80	+0.18	24.24	20.62
291	1.91	21.82	7.52	6.95	5.20	+0.57	-1.75	+1.14	-3.50	22.96	18.32
CUTTING.											
292	1.39	20.78	12.20	11.35	10.52	-0.85	+0.83	-1.27	+1.24	19.51	22.02
293	4.51	27.02	9.56	7.98	6.22	-1.58	+1.76	-2.37	+2.64	24.65	29.66
294	5.72	29.44	8.40	6.52	4.27	-1.88	+2.25	-2.82	+3.37	26.62	32.81
295	6.85	31.70	7.06	5.10	3.02	-1.96	+2.08	-2.94	+3.12	28.76	34.82
296	8.61	35.22	7.53	5.28	2.76	-2.25	+2.52	-3.37	+3.78	31.85	39.00

The first column contains the number of the central stakes, reckoned from the commencement of the work, which are convenient for reference.

The second column contains the depth of cutting or the height of embankment, as the case may be, at that point on the centre line.

The third column, the computed half width from the centre line to the edge of the cutting, or foot of embankment, upon the supposition that the ground is horizontal at right angles to the centre line, this half width, as before explained, (page 2,) is found by multiplying the central height by the ratio of the slopes, and adding to the product half the width at the base of the railway.

The fourth, fifth, and sixth columns contain the readings from the levelling staves at the centre stake, and at the approximate points E and H, (see last diagram.)

The seventh and eighth columns contain the differences of level between the centre stake and the above approximate points. These numbers are simply the differences of the quantities in the three preceding columns, (except at stakes 286 and 290, which we shall presently explain,) and the signs + or - denote whether they are positive or negative quantities as respects the centre, and the approximate points E and H.

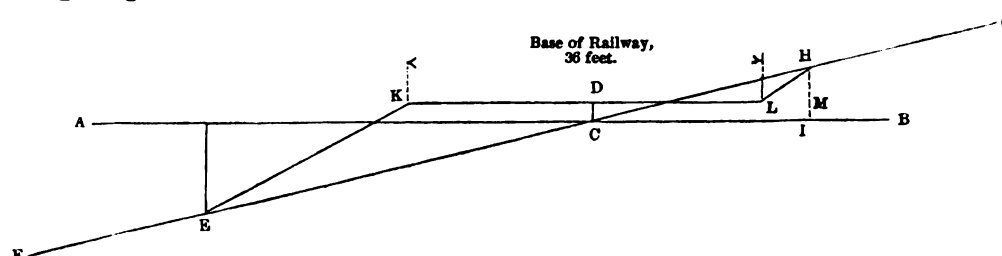
The ninth and tenth columns contain the differences of level (contained in columns 7 and 8) multiplied by the ratio of the slopes, and must have the same signs + or - as the corresponding numbers in the preceding columns.

The last two columns contain the final half widths, obtained by adding or subtracting, according to the prefixed signs + or -, the numbers in the two preceding columns to the computed half width contained in column 3.

After the explanations already given, the reader can find no difficulty in tracing the steps of the example, except perhaps with the stakes 286 and 290, where the difference of level on the north side is represented by two numbers bracketed together, one having the sign + and the other -: for the stake 286 the real difference of level on the north side the centre is a rise of 1.50, that is, the approximate point H is 1.50 feet above the centre stake; but it happens that the height of the embankment itself at that point is to be but 1.43 feet (column 2); therefore the approximate point H is above the intended top of the embankment, and consequently will not represent the foot of an embankment, but the edge of a cutting, and therefore the calculation for the half width on the north side must be treated as for a cutting whose depth is equal to the *height of the approximate point H above the intended top of the embankment*, or in other words, the *excess* of the difference of level between the centre stake and the approximate point H, above the intended height of the embankment, is the quantity to be entered in the column (7 or 8) "difference of level," and to be computed as for a cutting instead of embankment. In the case of stake 286 this excess is 0.07, to which is prefixed the sign plus; this sum multiplied by the ratio of the slope being additive (for a cutting) on the elevated side of the centre, as before explained.

For the stake 290, the north side of the line (column 6) is 1.34 higher than the centre stake, and it being embankment, would have the sign - prefixed (as shewn by the lower number, column 8); but the central height of the embankment at that point is but 1.22 (column 2); therefore, $1.34 - 1.22 = 0.12$, which is the depth of cutting on the elevated side, and when multiplied by the ratio of the slopes, is to be added to the computed half width to obtain the correct result. When the surface of the ground is much inclined at right angles to the centre line, the numbers to be operated upon become proportionally large.

As it is a case of frequent occurrence that one side will be a cutting when the other is an embankment, we wish it to be well understood, and therefore annex the following diagram to illustrate it.



The line FG represents the natural surface of the ground, AB the horizontal line at the centre stake, CD the intended height of the embankment, KL the width or base of the railway, 36 feet, part of which is an embankment and part in cutting; the point E , or foot of the embankment, will be determined in the usual way, as explained at page 5; but the point H , which is to be the edge of the cutting, must be found by subtracting DC (the height of embankment) from HI (the difference of level), the remainder, HM , (which is *the excess of the difference of level between the centre stake and the approximate point H above the intended height of embankment*), multiplied into the ratio of the slope, must be added to the computed half width, or in other words, treated as for a cutting, to obtain the said point H as before stated. By reversing the diagram (or this page) the corresponding case will become evident, namely, when the centre line is in cutting, and one side on embankment, while the other is in excavation, and the mode of proceeding will at once strike the reader after perusing what we have above written.

MEMOIR OF WILLIAM JESSOP.

BY SAMUEL HUGHES, C.E.

THIS engineer has been styled the connecting link between the first and second generations of civil engineers in this country. To the former belong Smeaton and Brindley, who, though almost without rivals in their early days, lived to behold their immediate successors, Mylne, Dodd, Jessop, and Whitworth, ably pursuing the same industrious and useful career, extending and expanding the ideas of their revered predecessors, arranging and reducing to system the heterogeneous details of their laborious profession, and paving the way with the public and in society for an entirely new and more strictly professional race of engineers, the foremost and greatest of whom are unquestionably Telford and Rennie.

It is interesting to trace the connexion subsisting between the earlier and more recent of these worthies, as it shews how each advanced into public estimation, under the shelter, as it were, of some other who had acquired sufficient renown to secure consideration and respect for his successor. Thus, while Jessop received his education under the illustrious Smeaton, Whitworth, his contemporary, had enjoyed the advantage of association with Brindley for the purposes of professional instruction. To come down also to a later day, we shall find Telford acting under Mr. Jessop in the Ellesmere Canal, and for several years at least in the Caledonian Canal also, during which time he derived great support and assistance from the high standing and general respect which his patron commanded. In like manner the great Mr. Rennie was introduced to the engineership of the Lancaster Canal, on the recommendation and by the advice of Jessop, who, occupying for many years the foremost rank in his profession, had the honour of advancing into active service some of the ablest engineers of that day.

The father of Mr. Jessop was engaged under Smeaton in superintending the erection of Edystone Lighthouse, and William Jessop, the subject of this memoir, was born at Plymouth in the year 1745. When young Jessop had attained the age of sixteen, his father died, leaving the guardianship of his family to Smeaton, who thenceforth adopted William as his pupil, and determined to bring him up to his

own profession. With Smeaton he continued for ten years, and very great must have been his opportunities of acquiring knowledge during this the busiest part of Smeaton's active career.

It is not generally known that in 1791, a year before his death, Smeaton formally retired from the profession, issuing at the same time a circular to inform his friends of his desire to dedicate the remaining years of his life to a description of the works executed under his direction*.

After leaving the service of Smeaton, Mr. Jessop was engaged for several years in improving the navigation of the rivers Aire and Calder and of the Calder and Hebble, in Yorkshire. He was also employed on the river Trent, in Nottinghamshire, and these works appear to have afforded his principal occupation for some time after he left Smeaton. A few years before the retirement of the latter, his pupil seems to have been getting into active employment, as we find him about the years 1788 and 1789 reporting on the navigation of the Sussex Ouse and the drainage of Laughton Level in the same county, while at this time he had also the honour of being called on by the Commissioners of the Thames and Isis, to advise on the works they had undertaken and were about to execute for the improvement of this important navigation.

In the three following years, 1790-2, his professional employment appears to have greatly increased. He was now actively engaged in prosecuting various important canals in connexion with the great central navigation of the Trent. Amongst these are the Cromford Canal, penetrating amongst the mountains of Derbyshire into the rich mineral districts of that wild, romantic country; the Nottingham Canal, which connects the Cromford with the Trent at Nottingham; the Loughborough and Leicester navigation, connecting the Ashby coal-field with the navigable part of the Soar and with Nottingham, thus opening an important communication with the Trent on

* As this circular is probably in the possession of very few persons at the present day, and as it may amuse some of our readers, a copy of it is here inserted *verbatim*:—

“ Mr. Smeaton begs leave to inform his Friends and the Public in general, that having applied himself for a great Number of Years to the business of a *Civil Engineer*, his wishes are now, to dedicate the chief part of his remaining Time to the Description of the several Works performed under his Direction. The Account he lately published of the Building of *Edystone Lighthouse* of Stone, has been so favourably received, that he is persuaded, he cannot be of more Service to the Public, or shew a greater Sense of his Gratitude, than by continuing to employ himself in the way now specified. He therefore flatters himself, that in not yielding to the many applications made to him lately for further Undertakings, but confining himself in future to the Objects above mentioned and to such occasional Consultations as will not take up much Time, he shall not incur the Disapprobation of his Friends.

“ Gray's Inn, 6th October, 1791.”

the one hand, and with Nottingham and the whole south of England on the other. Besides this system in connexion with the Trent, he projected and commenced at this period the Horncastle navigation, which, besides acting as a valuable drainage for this part of the fens, was productive of great benefit to a large district, which it brought into communication with the river Witham, which latter is navigable to the sea in one direction, and in the other through Lincoln to the Trent. But a larger and more important work than all these was the Grand Junction Canal, which connects the whole inland navigation of the country with the metropolis, by means of a line traced in a diagonal direction across the two formidable ranges of hills peculiar to the secondary formations of England.

The year 1793 also originated several great projects, amongst which were the Grantham Canal, supplied by vast artificial reservoirs, and extending from the river Trent, through a rich pasture district of the new red sandstone, and winding for many miles through the broad and fertile vale of Belvoir up to Grantham, at the base of the Lincolnshire hills, the furthest point to which it is possible to penetrate in this direction. The Barnsley Canal, which opens up an immense amount of mineral wealth in the Yorkshire coal-field, and brings it into communication with the river Calder and the Dearn and Dove Canal; and lastly, the great Ellesmere Canal, which completes a communication between the Severn and the Mersey, and ramifies in numerous directions amongst the rugged hills and romantic valleys of North Wales. Such were a few of the great works which Mr. Jessop was engaged in preparing up to the year 1793, before which time also he had been called into Ireland, and was taking an active part in carrying on the public works which had been undertaken under the authority of Parliament in that country.

The execution and management of the numerous works which have here been glanced at must have occupied most of Mr. Jessop's time during the next few years; but the dawn of the following century was the signal for another torrent of speculation which, in addition to canals, began now to be directed towards docks and railroads. The promoters of the first great public dock establishment in the metropolis called upon Mr. Jessop to conduct their works, and he had the honour of completing the great project of the West India Docks, with their numerous accompanying details, in a manner which would alone entitle him to rank among the greatest engineers which this or any other country has ever produced. Scarcely were these great docks completed, when Mr. Jessop was required by the citizens of Bristol to effect a great and comprehensive measure of harbour improvement, designed to place the port of Bristol at once in the foremost position with respect to commercial advantages. In all the various and complicated works connected with the great dock establishments of Lon-

don and Bristol, Mr. Jessop's labours were distinguished by consummate ability and a judgment which was rarely known to fail, although tried by the severe test of many novel and unprecedented practical experiments. He was now also astonishing the mechanical world by the effects produced on the railroads he had constructed in connexion with his canals in the mining districts of Derbyshire, Yorkshire, and Nottinghamshire, and busily engaged in tracing the first public railroads constructed in the neighbourhood of London. These are the well known tram-roads connecting the fullers'-earth pits and firestone quarries of Nutfield and Merstham with the Croydon Canal and the river Thames at Wandsworth. The last great work that remains to be noticed is the Caledonian Canal, which he was specially called upon to survey before its commencement, and of which he continued to be the consulting engineer for many years.

I shall now proceed to notice, as nearly as possible in the order of time, some of Mr. Jessop's principal works, with some few of his reports which I have been fortunate enough to procure, judging this course preferable to any attempt at a regular connected history of events, which would necessarily require many interruptions, and such frequent reference to reports and other documents, as to break and destroy its continuity.

PROJECTS FOR NAVIGATION AND DRAINAGE IN SUSSEX.

The navigation of the river Ouse, in Sussex, and the drainage of the extensive levels through which it flows, have long been objects of great importance to the neighbouring proprietors, who, as far back as 1767, engaged the talents of Smeaton relative to the drainage of Lewes Laughton Level.

In 1788 Mr. Jessop examined the river, and presented a valuable report on the proposed navigation from Lewes to Lindfield, which latter is eighteen miles above Lewes bridge. This report is principally occupied with the advantages to be derived from the conveyance of chalk and coals into the interior. The river has its sources in the extensive clay district of the weald, and at Lewes enters the chalk country, and pursues its course to the sea through a deep gorge in the range of the Sussex Downs. Few circumstances, then, could be better calculated to develope great agricultural benefit than a navigable communication between a great extent of cold, wet, clay country and an inexhaustible supply of chalk, the very material of all others which is the most necessary to the profitable cultivation of such a clay. Mr. Jessop observes that chalk is now (1788) carried in many cases even as far as eighteen miles, at an expense of 9s. per ton, and seeing that the navigation will enable the farmers to carry it the same distance for less than 3s., he appears quite justified in coming to the conclusion that much greater quantities will in future be used, not only because those

who have hitherto used an insufficient quantity, owing to the great expense, will adopt the process of liming on a more extensive scale, but because many others will be induced to try it who were formerly excluded from the advantage of procuring it at all. He estimates that an area of 108 square miles, or 69,120 acres, will be placed within easy reach of the navigation, and allowing half this area for wood land, grass, and waste, thinks it fair to assume that there will be 34,560 acres of arable land to be supplied with chalk by means of the river when made navigable. The usual calculation for the quantity of chalk required for liming land was then at the rate of four tons per acre once in four years. This is equal to one ton per acre per annum, and gives for the whole district a quantity of 34,560 tons annually. The carriage of even two thirds of this would produce a large profit to the undertakers of the navigation.

The general breadth of the river above the tideway at Lewes being not more than 14 feet at the surface of the water, Mr. Jessop proposes to make it 24 feet wide at top, 13 feet at bottom, and four feet deep, with occasional wider places for passing. The locks are to be built of timber, 50 feet long in the chamber, and 12 feet six inches wide, so as to admit boats of 45 feet in length, 12 feet breadth, drawing $3\frac{1}{2}$ feet of water, and carrying 30 tons. The necessary works are estimated to cost £16,380, including £1,980 for improvements of the river below Lewes, down to its mouth at Newhaven.

This report does not appear to have been immediately acted upon; but in 1790 an Act was obtained for extending the navigation of the river from Lewes bridge up to Cuckfield, when Lord Sheffield, Sir Godfrey Webster, and others, were incorporated under the name of the "Company of Proprietors of the River Ouse Navigation." Mr. Jessop was therefore again applied to, and he now furnished a plan of the locks to be built, and a short specification of the other necessary works. As a specimen of his clear and brief yet expressive style, the following letter to Lord Sheffield, the chairman of the company, may be interesting :

"MY LORD,—You will receive with this plans of a lock and its several members, which will give the necessary information to any person who has been employed in works of a similar nature; and, the width and depth of the river and cuts being specified, any person that can take the dimensions of the river in its present state, will be able to ascertain what is necessary to be done to improve it. I have said nothing of the bridges nor of the floodgates and weirs for discharging the water in wet seasons, which will be similar to those which they have at the mills. If you can let the lock building, and cutting of the river, you will have time enough to consider of the lesser

matters, as they are not necessarily so connected with the former as at all to interfere with them.

“ I am going into Yorkshire and shall return here about the 21st, after that, till the 26th, a letter would find me at Mason’s, at Matlock Bath, and from thence I shall go into Herefordshire, and to Dublin, where, if your lordship should honour me with a letter, I shall leave my direction at the post-office. I am your lordship’s most obedient servant,

W. JESSOP.”

“ Newark, May 13, 1790.”

The specification referred to in this letter is an excellent example of the few and simple particulars furnished by the early engineers to their contractors. The spirit of litigation must have been far more subdued than it is in these days, and there must have been much more of mutual confidence between the engineer and the person undertaking the work under his directions.

It will be observed that the use of brick for the sides of the locks has been substituted for the timber mentioned in his report of 1788.

SPECIFICATION OF THE WORKS ON THE OUSE NAVIGATION.

The locks to be built conformable to the drawings, of well-burnt bricks and good mortar. That for the front courses to be made of lime that will set in water, mixed in the proportion of one bushel of lime to two of clean washed sand, or if there is more sand, provided it will work with the trowel, so much the better. The body of the walls to be grouted with mortar in a fluid state, mixed in the proportion of four or five bushels of sand to one of unslacked lime; the lime not to be made up with water till immediately when used.

In locks of seven feet rise and upwards, the walls should be half a brick more in thickness.

The river to be everywhere dug to the depth of four feet below the level of a full pond where there are mills, or to the level of the upper threshold of the locks, over which the water must be kept up to four feet in depth. The width at bottom to be nowhere less than 15 feet, and the slopes on each side to be eighteen inches horizontal to each foot of perpendicular.

As the raising of the river by embanking above the surface of the land at the lock heads will considerably reduce the expense of the deepening at the lock tails, and that without any injury to the land, if proper drains are made (with trunks under the river) to convey the water to the next lowest lock in such places where the water

might otherwise be pent up by the embankment, those banks must be nine feet in width at the top on the towing-path side, and five feet on the opposite side, with slopes of 18 inches to a foot. They must be made water-tight by puddling, the puddle gutters to be dug a foot under the natural surface, and two feet wide.

There should be at least four passing places in every mile, 26 feet wide at bottom, none to be at a greater distance than 500 yards from the next above and below.

In widening the river where it is crooked, the whole to be taken off from the convex side in order to straighten it as much as may be.

The new cuts to be dug to the same depth as above directed for the river, and to have the same bottom width, and slopes.

W. JESSOP.

Newark, May 13, 1790.

The company shortly afterwards employed Messrs. Pinkerton, of Odiham, in Hants, as contractors to execute their works according to the above specification. They were accordingly carried on by them under Mr. Jessop's directions and completed to his satisfaction.

During the progress of these works, the company became aware of the necessity for some improvement of the river below Lewes, and as their Act gave them no powers to effect this, they again sought the assistance of Mr. Jessop relative to this improvement, and the drainage of the lands around Lewes. His report on this subject is addressed to the Right Honourable Thomas Pelham, and contains some excellent observations on the subject of drainage and embanking lands against the floods of rivers. The general measures which he recommends are new embankments and improvements of the old banks, straightening the river, and deepening its shallows.

Mr. Jessop's report was made in January, and these improvements were immediately commenced under the powers of an Act obtained in the same year, 1791.

THAMES AND ISIS NAVIGATION.

In the year 1789, Mr. Jessop was employed by the Commissioners of the rivers Thames and Isis, to report on the state of the navigation from Lechlade to Oxford and Abingdon. This report was called for in consequence of improvements which were rendered necessary by the increasing trade of the country, and particularly by the accession of trade from the west, produced by the Thames and Severn Canal, which joins the Thames at Lechlade. In order to carry these improvements into effect, the Commissioners obtained Acts of Parliament in 1788 and some former sessions, and they now consulted Mr. Jessop as to the best means of effecting their intentions. He accordingly surveyed the river, and made two reports, in which he described its condition at that time, and the improvements necessary, from

Lechlade down to Dorchester lock, a little below the town of Abingdon. At the time of these reports the great evils complained of were the want of depth to enable barges to carry their burden, the great loss of time in waiting for flash water, and the want of a convenient towing-path for horses. After some general observations, Mr. Jessop begins by stating the levels of the surface water at a great number of points, from Oxford upwards to Lechlade. From this statement, which was made on the authority of levels taken by Mr. Jessop himself, there being neither plan nor section of the river in existence at the time, it appears the rise from Oxford to the entrance of the Thames and Severn Canal, at Lechlade, is $52\frac{1}{2}$ feet. There are numerous shallows in the river which he recommends the Commissioners to remove, and in order to overcome the rise above stated, he proposes six pound locks, the operation of which he observes will be beneficial throughout the whole length of the river. The places where the pound locks are proposed are those where the greatest obstructions existed, and their advantage is strikingly exhibited by a glance at the system of navigation before the introduction of the locks. In order to get over any particular obstruction, boats had to wait for a flash of water, which would carry them over it, but as they could not float on so fast as the water, they had to wait at various places many days for repeated flashes. Mr. Jessop estimates that the improvements he proposes will enable a barge to make five voyages with a full lading in the time before occupied in making one with only half a cargo.

In these reports there are some practical observations relating to locks, and some peculiar notions advanced which it may be proper to notice. Speaking of the lock at Oxford, which had been already commenced by the Commissioners, on one of the cuts across a bend of the river, he observes that the site is not well chosen, and that the lock should be built at least 200 yards lower down. The reasons for this are well expressed, and appear to be sound and judicious. "It has been ascertained by experience," says Mr. Jessop, "that a tail cut from a lock on river navigations should be as short as possible; because, after floods, the eddy that is formed at the entrance into the river is generally the cause of a bar of sand or gravel, which is most easily to be removed by drawing the sluices of the lock; but when the water has to pass through a long tail cut, its motion is too languid to produce the necessary effect." In this particular case, also, the head cut from the lock to the river above can be made with much less difficulty and expense than the tail cut, so that a double reason exists for fixing the site of the lock nearer the lower end of the cut.

Speaking of the construction of locks, he observes, that the making of walls at all in the chamber of a lock, is not absolutely necessary; but that without them the sides of the lock would be liable to be washed away. Walls also serve to confine the size

of the lock chamber to the smallest dimensions which will answer the purpose, and prevent the waste of water and loss of time consequent upon filling a large chamber inclosed by earthen slopes. The strength of the walls, then, should be sufficient to enable them to resist the pressure of the earth behind them. "They are too generally," says Mr. Jessop, "made wide at the base and narrow at the top, being lessened by offsets behind, by which means, without earth behind them, they have a tendency to lean forward, and the pressure of the earth increases that tendency; and I have rebuilt many, otherwise substantial locks, merely because by the overhanging of the walls barges have been prevented from passing through them for want of the necessary width." He therefore recommends that the walls should be of equal thickness from top to bottom, and adds, that the counterforts, which are merely intended as land-ties, should not be built from the bottom, but be set on by steps on the slope of the lock pits, so as to lean against the earth and counteract its lateral pressure. The wall, he observes, will never fall backwards, and this construction, with much less materials than are otherwise necessary, will ensure it from leaning forward. His opinion is, that the sluices for filling and emptying locks are generally made too small; "they should never be made less than two feet square, so that a boat may pass in five minutes."

In his second report, Mr. Jessop submits to the consideration of the Commissioners the expediency of constructing the lock-chambers not with upright walls but with sloping sides, formed at an angle of 45 degrees, or more upright, and pitched with rough flat stones, about a foot in breadth, set edgewise like a street pavement, with a string piece of elm and some short piling underneath it at the foot. He is of opinion that this plan would be more economical, and would prevent the sides from washing in, particularly if the stones are set in moss, and wrecked full of gravel to prevent the earth from washing from behind through the joints. It may be observed that locks without chamber walls were at first proposed for the Caledonian Canal, and that there are several unwalled locks on the rivers Kennet and Lea^b.

Mr. Jessop observes that in the small bridges built by the Commissioners above Dorchester, there seems to be a want of economy in the use of timber; "for at the end of the bridges nothing more is necessary than to raise the ground a little with earth alone, which will cost but a few shillings, instead of which there is much wood thrown away in shoring up the earth at the sides; and I think the bridges are made wider than necessary, as four feet is quite sufficient for horses to pass over them." This seems to refer to the small towing-path bridges over the numerous creeks and

^b Rees's Encycl., Art. "Canal."

streams falling into the river, and which of course required narrow bridges for the passage of men and horses along the towing-path.

The Commissioners adopted Mr. Jessop's principal recommendations, and shortly afterwards undertook the construction of the pound locks in the situations which he pointed out.

CROMFORD CANAL.

This canal is about eighteen miles in length, and was chiefly designed for the export of coals, lead, iron, limestone, and other minerals from the mountain district of Derbyshire. The rugged nature of the country through which it is carried, rendered necessary some works of considerable magnitude, amongst which are the tunnel at Ripley, 2966 yards in length, with several shorter tunnels at other places, large cuttings and embankments, several extensive reservoirs, and large aqueduct bridges. The following are a few particulars relative to this work, extracted from the article "Canal," in Rees's Cyclopædia.

Top width of canal 26 feet. Boats employed are 80 feet long, 7 feet 2 inches wide, and 3 feet 4 inches deep; when loaded with 22 tons, they draw about $2\frac{1}{2}$ feet of water, and when empty, about 9 inches. Ripley tunnel is 9 feet wide at the water's surface, and 8 feet high from thence to the crown of the arch. Arch built of brick, except in some places where the rock was hard enough to stand without arching. Thirty-three pits or shafts were sunk in the construction of this tunnel, some of them on the summit of the hill being 210 feet deep. The cost of the tunnel was £7 per yard lineal; it intersects a valuable seam of coal, and this, together with excellent iron ore which was met with in sinking the shafts, has since been extensively worked. There is a large aqueduct bridge, 200 yards long and 30 feet high, over the river Derwent, near Wigwell, the river arch having a span of 80 feet, with two smaller arches by its side for carrying off floods and for a roadway. Near Frithly there is another large aqueduct bridge, 200 yards long and 50 feet high, with a river arch and two side arches, through one of which the turnpike road passes under the canal. These two aqueducts cost about £6000. Nearly over the Ripley tunnel there is a reservoir, which, when full, contains 50 acres of water. Its mean depth is 12 feet, and it contains about 2800 locks full of water, which is let out by a large pipe and cock in one of the tunnel pits. The embankment which holds up the water in this reservoir is 200 yards long, 12 feet wide at top, and 156 feet wide at the base in the middle of the valley. The canal has two other reservoirs, one of 20, and the other of 15 acres. For the cutting and wheeling of clay, $3\frac{1}{2}d.$ per cube yard was usually paid for a stage of 20 yards; for gravel, $4\frac{1}{2}d.$, and for stony ground, $4\frac{1}{2}d.$ per yard, and $4d.$ per

cube yard extra for all stones picked out and stacked. The whole cost of the canal exceeded £80,000.

This canal extends from the Erewash Canal, (which communicates with the Trent,) up the valley of the river Erewash, as far as Codnor Park iron works, where it turns off to the west, and passing close to the Butterley iron works, terminates at the town of Cromford. There are also numerous short branches to the various coal and iron works and limestone quarries in the neighbourhood of the line. The construction of the canal was authorized by two Acts obtained in 1789 and 1790, and the works were completed in 1793.

LEICESTER NAVIGATION.

This canal extends from the Loughborough Canal to the town of Leicester, and has branches to several mines and other places. The first Act was obtained for this work in 1791, and its execution intrusted to Mr. Jessop, by whom the line had been laid down. In December, 1793, the part between Loughborough and Mount Sorrel was completed, and the remainder of the line to Leicester was opened early in the following year. There are some heavy embankments on this canal, and an extensive reservoir on Charnwood Forest, with a long feeder for supplying the canal. At Leicester there is a convenient basin connected with the canal.

There is a considerable coal trade carried on by means of this canal, which also affords facility for the conveyance of limestone and granite, with the various commodities of timber, groceries, deals, and other articles which it supplies to Leicester.

This canal, which connects Leicester with the Ashby de la Zouch coal field, is formed entirely through the clays of the new red sandstone, and at one part of its course passes close to the base of the famous hill called Mount Sorrel, which is composed of sienite or granitic trap, and has for many years furnished vast quantities of metalling for the roads near London.

The stone is taken by this canal to Leicester, whence it is sent southward by the Leicester Grand Union Canal, which falls into the Grand Junction, and thence, by this latter, direct to London.

Many parts of the Holyhead road, and numerous other important turnpikes in the neighbouring counties, have been greatly improved by the use of this hard stone, which is to be met with at almost every considerable town along the whole line of canal to London.

NAVIGABLE COMMUNICATION BETWEEN THE RIVER WITHAM AND THE TOWN OF
HORNCastle.

In a report on this project, two separate proposals are examined; the one for making the river Baine navigable from its confluence with the Witham up to Horncastle, and the other for cutting a navigable canal from Horncastle down to some point on the Witham between the town of Lincoln and its confluence with the Baine. The principal advantages of the river line are, that it will take a less quantity of water from the mills than the canal, will be encumbered with less bridges, and will accommodate a greater number of villages in its vicinity. On the other hand, it will be sometimes liable to interruption by floods, and to obstruction by the sand which these will bring down. The canal line is also three miles shorter than by the river, and falls into the Witham four miles nearer Lincoln than the river Baine, so that the whole voyage to Horncastle will be seven miles shorter by the canal. Mr. Jessop states that, before seeing the country, he thought most favourably of the river line, but in his present report he is inclined to recommend the canal. A calculation is thus made of the quantity of water available for each line. The flow of water in the Baine, in dry seasons, is equal to ninety-eight locks full per day, taking a lock of seven feet rise to contain 170 tons of water. In addition to this, some small streams below the point where the river was gauged will produce about six locks full, making together 104 locks full per day. Mr. Jessop calculates that the trade on the navigation will employ, on an average, one boat in a day up, and one down, which will take two locks of water; that the leakage of the locks may be equal to two locks more, and that the waste by absorption in the new cuts on the river line, and by exhalation from the increased surface, may be four locks more, making in all eight locks per day. According to this calculation one thirteenth part of the water would be taken from the mills in dry seasons.

On the canal Mr. Jessop allows, as in the other case, four locks for the trade and leakage of locks, but, in addition, he allows twelve more for the absorption, exhalation, and casual leakage of banks, because little or none of this water will return to the river, as it might from the leakage of short cuts on the river line. This will make in all sixteen locks full per day, which is equal to one sixth of the whole quantity available for the supply of the canal in dry seasons. Estimating the dry season at four months in the year, Mr. Jessop observes, that this will in effect be taking one eighteenth part of the annual power that works the mills. To show that this apparent abstraction of their power is of very little consequence, he goes on to say, that

the mills are all capable of being so improved as to do one fourth more work with the remaining five sixths of the water, than they can do at present with the whole. It is easy, therefore, to make compensation to the mill-owners, either by a sum of money, or by improving their mills at the expense of the undertakers of the navigation. The report concludes by a detailed estimate of the comparative expense, from which it appears that the river line would cost £12,233, and the canal £12,544.

This report was made in 1791, and an Act was obtained in the following year for making the river Baine navigable up to Horncastle, a distance of eleven miles from Tattershall, on the north bank of the Witham. In pursuance of this Act, the river was widened and straightened by a number of short cuts to take out the bends. The cost of this work, which is now known under the name of the Horncastle Navigation, was nearly £45,000, a sum very greatly in excess of Mr. Jessop's estimate, as it includes an extensive basin at Horncastle, and other works not originally contemplated. The navigation was opened in the year 1802, and has been productive of great advantages, from the connexion which it opens up between the agricultural country around Horncastle and the great coal fields and manufacturing districts of the midland counties. By means of the river Witham, the Horncastle Navigation communicates with Lincoln and Boston, and by means of the Foss Dyke Navigation, which commences at Witham, a way is opened to the Trent, and the whole midland system of canal and river navigation.

In connexion with the Horncastle Navigation, and with the communication from the Witham to the Trent, Mr. Jessop made another report in 1791, on the improvement of the navigation from the Witham through the High Bridge of Lincoln, into the Foss Dyke Canal. The passage through the High Bridge, at the time of this report, was twenty feet wide, and could only be used by small boats or lighters drawing about a foot of water. The High Bridge was built on a wooden floor, which was about eighteen inches below the surface of water in its lowest state. Mr. Jessop describes the practicability of taking up this floor, without any danger to the bridge, of deepening the channel under the bridge and on both sides of it, and underpinning the abutments and retaining walls above and below the bridge, so as to admit vessels of the largest class to pass through it. Instead of deepening the river through the High Bridge, however, Mr. Jessop proposes the adoption of Sincel Dyke, which is a cut from the river above Lincoln to the river below the city. A short length of canal is necessary in connexion with this latter project, together with a lock, the whole expense of which he estimates at about £1500. It appears that this recommendation has not been carried out, the present communication being carried on through the High Bridge of the city. The works necessary to render this

communication complete, were undertaken under the same Act of Parliament as that which authorized the incorporation of the Horncastle Navigation Company.

NOTTINGHAM CANAL.

This navigation is fifteen miles in length, and extends from the Cromford Canal into the Trent, opposite the junction of the Grantham Canal. Near Amsworth there is a reservoir for the supply of this canal, with a self-regulating sluice, which lets out near 3000 cubic feet of water per hour for the use of the Erewash Canal and of certain mills in the neighbourhood. The Act was obtained in 1792, and the canal completed in 1802. Cost, about £75,000.

THE GRAND CANAL OF IRELAND.

Mr. Jessop was at one time the principal engineer of this work, which commences in a large basin connected with the river Liffey and the Docks, and extends through the counties of Dublin, Kildare, and the King's County, to Tarmonbury on the Shannon, a length of $61\frac{1}{2}$ miles. The canal is 5 feet deep, with locks 80 feet long and 16 feet wide in the clear, built of stone. The canal was commenced soon after the year 1753, and about 1770 the construction had proceeded as far as the Bog of Allen, when it stood still for some years; but the works were renewed, and the line was opened in 1804.

At the period of Arthur Young's tour in Ireland^c, he states that fourteen miles of the Grand Canal are completed, and innumerable locks, quays, bridges, &c., absolutely finished; and although he sees no prospect of the work paying, he urges the propriety of completing this in common with numerous other public works which had been undertaken during the flourishing state of the Irish revenue in the preceding twenty years. It appears that up to 1767 a sum of £73,646 had been granted by Parliament for the works of the Grand Canal, but during the next four years the highest grant was only £2000; so that the works must then have been virtually suspended.

THE GRAND JUNCTION CANAL.

The Grand Junction Canal claims particular notice, not only as one of Mr. Jessop's principal works, but as one of the most important links in the system of inland navigation by which the metropolis is connected with the great coal and iron fields of

^c "Tour in Ireland," by Arthur Young, Esq., F.R.S. London, 4to. 1780.

the midland counties, the busy manufacturing towns and districts adjacent to these, and the vast extent of rich agricultural country by which the whole are surrounded.

The Oxford Canal has been already mentioned in the life of Brindley, as completing the chain of communication between the metropolis and the central districts of England. This line of navigation, however, is extremely circuitous, and has always been attended with great disadvantage, arising from the tedious and imperfect navigation of the Thames below Oxford. In order to remedy the delays and inconveniences of the Oxford Canal and river Thames navigation, the Grand Junction Canal was proposed about the year 1790, as a comparatively direct line from the metropolis to the Oxford Canal at Braunston in Northamptonshire. The length of the old navigation from Braunston to Oxford, and thence by the Thames to Brentford, is 154 miles, while the whole length of the Grand Junction Canal from Braunston to Brentford being only 90 miles, it effects a saving of 64 miles out of 154.

The line commences at Braunston in Northamptonshire, within a mile of which place it rises 37 feet to its first summit. This summit level is $4\frac{1}{2}$ miles long, and has a tunnel 2045 yards in length, through which the canal penetrates the marlstone ridge of the lias formation. The canal then falls 60 feet into the valley of the Nene, and continues on one level for upwards of 13 miles, passing close to Gayton, near to which place a branch goes off to Northampton. In the course of this long level is the famous Blisworth Tunnel, 3080 yards in length, through the inferior oolite and the shales of the lias. The canal next falls into the valley of the Ouse, where its level is 172 feet below that of the Braunston summit. Following the valley of the Ouse, the line passes close to the town of Stony Stratford, from which a branch goes off to Buckingham. It then continues by Linford Magna, passing round in a great curve through the clay district of the oolite formation, and proceeding by Fenny Stratford and Leighton Buzzard, through the sands and gault clay of the green sand formation, rises up to the summit level at Tring by a lockage of 192 feet^d. The canal attains this level near Marsworth, about 51 miles from its commencement at Braunston. The summit level, $3\frac{3}{4}$ miles in length, is carried through an extensive chalk cutting upwards of two miles long, and averaging nearly 30 feet deep. The course continues through the chalk country by Berkhamstead and Hemel Hempstead, where the

^d These are the levels of the canal as originally executed, but during the progress of the works it was determined to avoid four locks on the south side of the Ouse, and five on the north side, by carrying the canal across the valley on a level about forty-two feet higher than was originally intended. It will be seen that the great embankment necessary for this purpose was finished within a few months after the completion of the Blisworth tunnel.

canal falls into the valley of the Colne, continuing by King's Langley and Harefield to Uxbridge. Near King's Langley there is a deep cutting on a level of the canal 127 feet below the Tring summit. Beyond Uxbridge the canal passes through a flat district of country consisting of the plastic clay of the London basin, and crossing the rivers Cran and Brent, terminates in the river Thames at Brentford, near the mouth of the Brent. The course of this canal between Braunston and King's Langley, comprising the pass through the oolites at Blisworth and the passage of the Tring summit, is nearly identical with that which has since been selected with so much ability by Mr. Robert Stephenson for the London and Birmingham Railway.

Besides the main line of the Grand Junction Canal which communicates with the Thames at Brentford, there is a branch to Paddington which leaves the main line at Bullbridge, five miles above Brentford. This branch, which is called the Paddington Canal, passes through a favourable district of clay country, and has only one lock on its whole course of fourteen miles. The Regent's Canal, which proceeds from the Paddington Canal round the north side of London to the Thames at Limehouse, completes the communication between the Grand Junction Canal and the lower part of the river.

The Grand Junction Canal was planned by Mr. Barnes, but in 1792 Mr. Jessop was requested to survey the line, and to report to the committee his opinion of the project. The report made in pursuance of this request is dated 24th October, 1792, and considers three main questions:—

1st. The general practicability of the canal.

2nd. Whether the line that has been chosen is in general the most eligible.

3rd. Whether such parts as will be particularly expensive could be avoided.

With reference to the first head, he entertains no doubt of the practicability.

On the second head, he is of opinion that the terminus of the canal at Braunston, that is, its junction with the Oxford Canal, has been judiciously fixed, as well as the point where it is proposed the canal should terminate in the Thames at Brentford. With respect to the course of the line, he thinks it extremely favourable and free from obstacles, considering the difficult nature of the country, and the successive ranges of high ground to be intersected. The length of the canal, he observes, is only fifteen miles more than that of the roads leading from one extremity to the other.

He then proceeds to comment on the principal difficulties which the line presents; namely, the large works at Braunston, Blisworth, Langley Bury, and Tring; deciding that from all the observations and inquiries he has made, these obstacles are unavoidable, and that the country has been explored with great assiduity by Mr. Barnes, and the ground chosen with much judgment.

He next comes to the dimensions of the canal, its locks, and tunnels, which he states as follows :—

Width of canal at bottom	28 feet
Ditto, ditto, at water surface	42 „
Depth of water	4½ „
Width of locks	14½ „
Length of ditto in the chamber	80 „

These, he observes, will admit boats that will carry from fifty to seventy tons, and such as will navigate with safety on the Thames, on the Trent if the communication should take place with the navigation to Leicester, and on the Mersey if the present canals should hereafter be widened, which is not improbable. Locks of this width will contain two of the boats which now use the narrow canals, and those boats may also pass each other in the tunnels, which are intended to be 16 feet in width, 18 feet in height, and to have at least 6 feet depth of water.

Respecting the supply of water for the canal, Mr. Jessop observes that, as there are two summits, the quantity consumed must be more than one would require. The loss by exhalation and absorption is not at all increased, however, by this circumstance, the principal effect of which is in fact to render a double quantity of water necessary for those boats which pass both summits. Mr. Jessop had not made any personal examinations or measurements of the streams, in order to ascertain the quantity of water which they would yield to each summit; but, in referring to Mr. Barnes's admeasurements, he has very little doubt that the natural streams which can be brought to each summit will yield a sufficient supply for a moderate trade without the use of reservoirs to store up the water of floods. In this part of the report there are some curious practical remarks with reference to the variable quantity of water to be found in the streams of different districts according to the nature of the season. "In clay soil, such as at Braunston, the extremes of wet and dry seasons differ as much as one thousand to one; in chalky and gravelly soils the difference is seldom more than as four to one; for in the former case heavy rains produce great floods, and little is absorbed; in the latter case there are seldom any floods, for almost the whole is absorbed; and it only operates for a while to increase the supply by the springs, which may be considered as the discharges of natural reservoirs, dispensing frugally for many months what would be lavished from the surface of clayey soil in a few days." The remainder of the report is principally occupied with remarks on the branches proposed to be cut from the main canal to Daventry, Northampton, Stony Stratford, and Watford.

Mr. Jessop's estimate for executing the canal, exclusive of branches, was £372,175

The branch to Northampton 18,785

The branch to Daventry 6,000

The other two branches not having been surveyed, their cost could not be stated.

The following are the lengths and lockage of the Grand Junction Canal, as stated on the map which accompanies Mr. Jessop's report:—

	M.	F.	C.	FEET.
From the Oxford Canal to near Braunston Mill	0	7	3.20	37 rise
From near Braunston Mill to the end of Long Buckby Parish	4	2	0.30	level
From the end of Long Buckby Parish to the end of Whilton Parish	0	5	5.10	60 fall
From the end of Whilton Parish to Stoke	13	3	5.90	level
From Stoke to the river Ouse	6	4	4.10	112 fall
From the river Ouse to near Marsworth	25	1	6	192 rise
From Marsworth to near Cow Roast	3	6	0.50	level
From near Cow Roast to Two Waters	6	6	0.50	127 fall
From Two Waters to near Langley Bury	4	6	2.40	level
From near Langley Bury to the river Thames	23	6	5.60	268 fall
	90	1	3.60	

Besides the tunnels and the numerous deep cuttings on this canal, there are numerous other heavy works, consisting of aqueducts, embankments, reservoirs, and weirs. At the crossing of the Ouse river, near Wolverton, there is an immense embankment, by which five locks on the north side, and four on the south side, have been avoided. These locks have been built and allowed to remain, so that in case of any accident to the great embankment, the canal could be carried at the lower elevation through the locks. There are also large embankments at Weedon Beck and at Bugbrook. The principal aqueducts are that of three arches in the Wolverton embankment, and those over the river Brent and another stream on the Paddington branch. There are five large reservoirs, intended either to supply the canal or the mills whose water has been diverted. The Aldenham reservoir covers $68\frac{1}{2}$ acres, that at Willstone 40 acres; and those at Weston-Turville, Braunston, and Daventry are also considerable. There are numerous weirs or tumbling bays, where the canal intersects mill dams in the Coln valley between Great Berkhamstead and Uxbridge, and others of great size at the crossing of the Towcester river. The Blisworth tunnel was completed in March, 1805, when the whole line was opened, the locks in the Wolverton valley then forming part of the navigation. In August of the same year the Wolverton embankment was completed, and the navigation opened across the valley on the high level, by means of which the lockage already spoken of was avoided.

The article "Canal," in Rees's Cyclopædia, has some useful particulars relating to this tunnel, which was just completed at the date of that article (1805).

"The internal width of this tunnel is $16\frac{1}{2}$ feet, the depth below the water line to the inverted arch 7 feet, and the soffit or crown of the arch is 11 feet above the same line. The side walls are segments of a circle of 20 feet radius, the top arch one of 8 feet radius. The side and top walls are 17 inches, or 2 bricks thick, and the bottom or inverted arch $1\frac{1}{2}$ bricks, or 13 inches. The mortar was composed of one bushel of Southam lime (*blue lias*) to 3 of good sand. Six inches under the water line, on each side of the tunnel, slide rails of fir, 5 inches square, to keep the barges off the walls, are fixed by pieces of oak let into the wall below them, which rails project 9 inches from the wall, and have at every 9 feet a chock of wood upon the rail, for the bargemen to set their pole against for shoving their barges along. We were told that this tunnel was contracted for at £15. 13s. per yard run; the soil principally a hard blue clay, with two or three thin rocks in it. Sufficient headings had been driven several years before at the Company's expense. The same contractors were paid $10\frac{1}{2}d.$ per cubic yard for excavating the deep cutting at one end of this tunnel, and $11d.$ per cubic yard for the other. The expense of driving the above headings was, we understood, from 36s. to 42s. 6d. per yard run. Nineteen tunnel pits, some of them 60 feet deep, were sunk for the use of the above tunnel, which cost about 30s. per yard in depth, including steining. In our inquiries respecting Braunston tunnel, on the same canal, we were told that 320 yards of the same were driven in quicksands, and that it cost £4800 extra on that account."

Such was the eagerness with which the shares in this concern were taken up, and such the prospects of success which the undertaking was expected to realize, that at some of the very first meetings for its promotion, and long before the Act was obtained, premiums of £20 and £30 were offered for the transfer of even small lots of shares in the concern.

The cost of this great undertaking, with all its branches and attendant works, has been about two millions sterling.

THE ELLESMERE CANAL.

The extensive line of navigation now known by this name, includes, in fact, two canals, namely, 1st, that executed by Brindley, from the river Mersey to Nantwich, and 2ndly, the line from Nantwich to Ellesmere, Chirk and Pont-y-cysylte, in the Vale of Llangollen, with branches to Weston Lullingfield, and Llanymyneoch, at which latter place it joins the Montgomeryshire Canal. The first of these navigations was

called the Chester Canal, and the second the Ellesmere Canal; and both Companies are now incorporated under the name of the "Ellesmere and Chester Canal Company." The whole length of the united canals is upwards of 109 miles; but the part with which Mr. Jessop was more immediately concerned is that described above as the original Ellesmere Canal, commencing at Nantwich.

The Act for this canal was passed in the year 1793, and Mr. Jessop, who, in conjunction with Mr. Dadford, had obtained the Act, was appointed principal engineer. Mr. Telford, who was then county surveyor of Salop, in which capacity he had become favourably known to many of the leading proprietors in that county, was offered the appointment of acting engineer, which he accepted. This is the statement made in his life by Mr. Telford himself, and it is clearly borne out by a fact which will presently be adverted to, notwithstanding some assertions which have been made, to the effect that Telford was merely the agent or superintendent of the Canal Company, and not an engineer at all at that time. If this statement has been made to detract from Telford's merit, with respect to the great aqueducts and other works on this canal, and to swell in a corresponding degree the credit of Jessop, the attempt appears quite gratuitous and unnecessary; for Telford acknowledges candidly enough the advantage he derived from consulting Mr. Jessop, on whose advice, in his own words, he "never failed to set a proper value."

The inscription on the aqueduct of Pont-y-cysylte clearly states, that Thomas Telford, F.R.S. L. & E., was engineer of the work; and it is remarkable that no other engineer is mentioned. Telford's testimonial from the Committee of the Ellesmere Canal Company, printed and circulated at their general meeting in 1805, affords also conclusive evidence, that whoever else was employed as engineer, he at least was one, for it states, "that the works have been planned with great skill and science, and executed with much economy and ability, doing him, (Mr. Telford,) as well as those employed by him*, infinite credit.

(Signed) "BRIDGEWATER."

As the Ellesmere Canal passes through a very rugged country, following the course of several circuitous valleys, which are flanked by mountains of great height, the works assumed a peculiar character, consisting of a great extent of rock cutting, with two tunnels, which were rendered necessary in passing through the rugged country between the rivers Dee and Ceriog, in the Vale of Llangollen. A great mountain lake, called Bala Pool, was dammed up, and furnished with a regulating weir for supplying the summit level of the canal with water. The principal works

* See Life of Telford, p. 49. London, 4to, 1838.

on the line, however, are the two great aqueducts of Chirk and Pont-y-cysylte, the former of which carries the canal over the river Ceriog, at an elevation of 70 feet above the water in the river, and the latter carries it across the Dee at an elevation of 127 feet. These great aqueducts are splendid specimens of the first style of masonry. The piers were carried up solid to a certain height, above which they were built hollow, with cross walls. The spandrils also above the springing of the arches were not filled in solid, but consisted of parallel, longitudinal, interior spandril walls, a method which had before been adopted by Mr. Telford in Kirkcudbright Bridge. But the grand peculiarity in these aqueducts was this, that instead of an immense puddled trough for carrying the canal across the arches, in accordance with the practice till that time in use, the bold and original idea was here conceived of constructing a water-tight trough of cast iron, in which the water of the canal was to be conveyed over the valleys. The immense importance of this improvement on the old practice, is apt to be lost sight of at the present day by those who overlook the enormous size and strength of masonry, which would have been required to support a puddled channel at the height of 120 feet. There were also frequent instances of the puddle cracking and swelling, and of the masonry settling and being rent by fissures, which suffered the water to escape. All these objections to the old form of aqueduct were removed by the invention of the cast iron trough, composed of ribs and plates, provided with flanges, and securely bolted and made water-tight.

That Jessop was consulted by Mr. Telford as to the adoption of iron for these works, and that he approved of the design, there can be no doubt; but I think there is no authority for saying that he either originally designed the cast iron troughs, or improved upon the proposals made by Telford. The fact is, that neither Telford nor Jessop is strictly entitled to the credit of originally applying iron as a trunk or trough for aqueduct bridges. The proposal to use iron for this purpose was first made by Thomas Eyton, Esq., chairman of the Committee of the Shrewsbury Canal, and referred by him to the consideration of Mr. Telford^f and Mr. William Reynolds. The plan was approved by these engineers, and a design made out, according to which an aqueduct, 62 yards long, was executed over the Tern Valley on the Shrewsbury Canal. Mr. Telford, in his account of the Ellesmere, refers to this previous use of cast iron under his directions, but makes no mention in his Life of the idea having been suggested by another person.

At the same time, although it appears clear that Mr. Telford proposed the use of cast iron to Mr. Jessop, the latter has all the credit of designing the vast height

^f Telford's account of the inland navigation of Salop in Plymley's Agricultural Report of Salop.

and proportions of these great aqueducts, which far exceeded any thing that had ever before been attempted. He being the principal engineer, the levels and general features were settled by him, and to him is due the bold and successful attempt of carrying the canal at this great height, instead of locking up and down into the valley, at so great an expense of time and water that the prospects of the whole concern would have been vitiated for many years.

It was scarcely to be expected that Mr. Jessop, from his position as chief engineer, could minutely adjust all the details of even large works like these; and it is at least highly indicative of his honourable and liberal mind, that he acquiesced at once in the judicious views of his acting engineer, to whom the more immediate charge of executing the work was committed.

GRANTHAM CANAL.

This is a navigation from the river Trent to the town of Grantham, in Lincolnshire. It may be considered as an extension of the Grand Trunk navigation, and the whole vast system of inland canal communicating with it, into a purely agricultural district of great fertility and importance. Its general course is eastward, in a very crooked direction, through the vale of Belvoir up to Grantham, which is situated on the flat clay country which skirts the base of the oolitic range of Lincolnshire hills. The line is thirty-three miles in length, and being mostly raised above the surface of the country, is on too high a level to receive the contents of the natural streams of the district, which are besides too insignificant to afford a sufficient supply of water. The canal is therefore entirely fed by water collected in reservoirs, which receive the flood water of the streams, and retain it for the use of the canal in dry weather. The reservoir at Denton, which supplies the summit level, is twenty acres in area and nine feet deep; and that at Knipton, which receives the flood waters of the Devon river, was originally made sixty acres, and nine feet deep, but in 1804 the banks were raised four feet higher. There was a violent parliamentary opposition raised against this canal, during which it was asserted that it was impossible to obtain a sufficient quantity of water to supply the lockage, &c. But Mr. Jessop ably contended that this was quite practicable by means of the reservoirs which he had designed, and he circulated a paper amongst numerous Members of Parliament and others, containing his views on this subject. The advantages of this canal to a purely agricultural country, which was formerly cut off from the supply of coal, limestone, and other minerals, must necessarily be very great, while at the same time new markets are opened for the consumption of its own agricultural produce, and thus a

general stimulus is given to the industry and prosperity of the district. The canal is said to have cost about £124,000.

BARNSELEY CANAL

Commences in the river Calder, and extends to the town of Barnsley, and to a basin at Barnby Bridge, in the West Riding of Yorkshire, a length of something more than fifteen miles. In the first two miles and three quarters of its course the canal rises from the Calder to a height of 117 feet, by means of fifteen locks. At ten miles from its commencement the canal forms a junction with the Dearne and Dove Canal, from which it rises an additional height of forty feet to its summit level. The level which communicates with the Dearne and Dove Canal is supplied by a large reservoir of 127 acres and a depth of forty feet in the deepest part, into which the water is pumped by a powerful engine from the long level of the canal. There is also another engine for pumping up water to the summit level. At Eym there is an aqueduct of five arches, each of thirty feet span, which conveys the canal over the river Dearne. The depth of the canal is five feet, and the locks are made sixty-six feet in length and fifteen in breadth, so that they are capable of receiving boats of the same size as those which navigate the Aire and Calder. The principal objects of the Barnsley Canal were to open a navigation from Sheffield and Rotherham to the other numerous and important towns of Yorkshire and Lancashire, and to bring into use the coal of Barnsley, Silkstone, and the neighbourhood. Mr. Priestley says that "the making of this canal has been of incalculable advantage to the agriculturists in its vicinity, by the facility which it has given for the introduction of Knottingley lime; and the advantage has been more particularly experienced by those who are employed in bringing into cultivation the vast tracts of moor land lying to the north and west of its termination at Barnby basin." The cost of this canal was upwards of £140,000, and it was opened on the 8th of June, 1799.

THE WEST INDIA DOCKS AND CITY SHIP CANAL.

It is difficult to conceive circumstances of greater embarrassment than those under which the trade of the port of London laboured for some years before the wise and admirable contrivance of establishing large floating docks was carried into effect. In the year 1793, when docks were first proposed, the port was frequented by 3500 sail of shipping engaged in foreign trade, and by more than double that number of coasting vessels. There were no means of accommodation for this large amount of shipping, except that afforded by two small docks, one of twelve and the other of eight acres, belonging to two individuals, Messrs. Perry and Wells. In consequence

of this, all that part of the river called the Pool, and thence up to the Tower, was constantly crowded with vessels, the greater proportion of which were coasters; and these, together with the timber ships, employed six sevenths of all the craft on the river to land their cargoes. These craft consisted of lighters, which occupied all the space in front of the wharfs and landing quays, and being the property of a small number of persons, the use of them was monopolized, and combinations created against the wharfingers and owners of valuable cargoes. The port usually contained from 1,000 to 1,400 sail of shipping, of which not more than 500 could lie afloat at low water at the various mooring tiers and chains in and from the Pool to the Tower. At this time our trade with all the world was increasing beyond the example of all former periods, and in addition to her old commerce with the Baltic and the Mediterranean states, London had now become the great storehouse and granary of Europe for the tea, coffee, rum, sugar, rice, and all the other valuable productions of the East and West Indies, from which fleets were constantly arriving in the river, bringing at one time 30 or 40,000 hogsheads of sugar, besides vast quantities of teas from China, with rice and bales of manufactured goods of enormous value from the possessions of the East India Company. The whole value of the imports at this time was £12,224,745, and that of the exports £12,660,463. The merchants engaged in this immense trade, as well as the revenue, were subject to incalculable loss from plunder and smuggling, in consequence of the want of accommodation for the shipping. All the wharfs and warehouses along the river were crowded to an incredible extent, as will readily be seen from the fact that they could not contain more than 32,000 hogsheads of sugar at one time, while upwards of 130,000 hogsheads required warehouse-room during that three months of the year when the East and West India fleets arrived. The loss by fire was enormous, owing to the crowding of the warehouses and the length of time which vessels had to lie in the river before they could be unloaded by the lighters. In one West India fleet three vessels were destroyed by fire in the river, their value amounting, with that of their cargo of rum, to not less than £90,000.

When the general complaints consequent upon this state of things had reached to a great height, the important measure of the West India Docks was undertaken, for the use of that particular trade. These docks are situated on the Isle of Dogs, and communicate with the lower part of the river below the island. Parallel to these docks is the City Canal, which was cut across the island in order to shorten the navigation round a great bend of the river at this place.

The West India Docks consist of an import and export dock, parallel to each other, and having an area respectively of thirty and twenty-five acres. At the Black-

wall end the two docks open into a basin of between five and six acres, and at Limehouse into a basin of two acres. The entrance locks are forty-five feet wide, and are capable of admitting vessels of 1,200 tons burden. At the highest spring tides the docks contain twenty-four feet depth of water, and afford sufficient space for 600 vessels, varying from 250 to 600 tons burden. There is here every accommodation for a most extensive trade: the import warehouses are capable of storing 170,000 hogsheads of sugar, besides containing ample space for rum, brandy, coffee, tea, and all the other productions of the tropics. The whole area occupied by these magnificent docks, their warehouses, sheds, &c., is not less than 295 acres of ground. The capital raised by the Company for carrying into effect this great measure was £1,380,000, and for a long time, during which they enjoyed the monopoly of the West India trade, their dividend was equal to 10 per cent. Of late years the rates have been lowered, and the profits are now understood to be about 5 per cent. The City Ship Canal, in which Mr. Jessop was also concerned, is cut across the Isle of Dogs, parallel to the West India Docks. Its length is a mile and a quarter, with a top breadth of 142 feet and depth of 24 feet. It was designed to avoid the tedious passage of vessels round a long bend of the river at this place, but since the employment of steam-tugs for towing vessels in the river the canal has fallen into disuse, and is now no longer a free passage, but is appropriated as a *depôt* for the reception of bonded timber. It may now therefore be considered as an additional dock, of about nineteen acres in extent.

Mr. Ralph Walker, who is said to have originally proposed the West India Docks, was the resident engineer, and a son of Mr. Jessop was also engaged as an acting engineer on this work. So anxious were the directors for the completion of the docks, that Mr. William Jessop himself was latterly two-thirds of his time personally engaged in superintending them, so that there is certainly some error in a statement which has been made, to the effect that he was consulting engineer to the Dock Company, at least if this statement is to be taken as implying that his connexion with them extended no further than the office of consulting engineer.

The West India Docks were commenced in February, 1800, and opened for the reception of shipping in August, 1802.

MR. JESSOP'S CONNEXION WITH THE CALEDONIAN CANAL.

It is singular that in the notice of Mr. Jessop in the first volume of the *Engineers' Transactions*, no mention is made of the Caledonian Canal, although it is perfectly notorious that he was the senior engineer of that work, that the plan and main features of its execution were settled by him even before consulting with Mr. Telford,

and that during the progress of the works he continued to be the chief engineer, in which capacity he made an annual report to the Commissioners.

It appears from Mr. Jessop's original reports on the Caledonian Canal that he clearly foresaw the difficulty of making it water-tight through a succession of strata so completely porous as those amongst which this magnificent work is carried. After making his survey of the line by desire of the Government in 1802, Mr. Jessop was of opinion that the whole valley of Glen Mhor ni Albanach, along which the canal extends from the Moray Firth on the east coast, to Loch Linnhe on the west coast, had been originally a great watercourse from sea to sea, and that the flow of this water had accumulated vast quantities of that water-worn gravel with which he conceived the valley to be filled. Since the time of Mr. Jessop, numerous examinations of this remarkable valley have been made by very skilful geologists, and although the angular structure of the gravel is opposed to the hypothesis of a water wearing action, yet his views with respect to the measures which should be adopted in carrying the canal through this very porous gravel have been completely confirmed, both during the progress of the works and in subsequent examinations. Mr. Jessop's decided opinion was, that the whole of the canal required a puddle lining, and it was most unfortunate for the credit of the concern, and those who were engaged in it, that this precaution was neglected.

Many different opinions have been hazarded to account for the abandonment of the views which he originally entertained on this subject. Some there are who have not hesitated to ascribe great blame to Mr. Telford, as the acting engineer, for not carrying out the intentions of his superior, while others—and principally those who acted under Mr. Telford on the works—insist with equal pertinacity, that he was in favour of puddling, but was overruled by the subsequent change which took place in Mr. Jessop's opinions. It can answer no useful or honourable purpose to revive, at this distance of time, the remembrance of animosity which has long since been hushed in silence. A task not less unworthy would be that of tracing, in exact detail, the proportion of censure and merit to be doled out to each of these deservedly great men, with respect to certain parts of the Caledonian Canal, which are confessedly not exactly all that its warmest friends could wish. Undoubtedly there were serious errors somewhere; great inconsistency and great rashness in throwing into spoil large quantities of clay between the Muirtown Locks and Torr Vane, and then attempting to carry the canal alongside the river Ness, through the most porous stratification that could be imagined, without any of the puddle lining for which the clay already spoken of was so admirably well adapted. But who is there now living that would wish to detract one iota from the merit of either Telford or Jessop, for

the mere paltry object of throwing an additional panegyric to the account of the other? Who is there that has ever seen the former—that stern, unbending, iron-visaged, yet kind and warm-hearted old man—has ever looked back upon his stainless character and blameless life, and reflected that he bore a name which no tongue has ever dared to couple with a single dishonourable act, and does not feel that it would degrade the spirit of this inquiry to pronounce without reservation, here Telford erred—and there Jessop displayed superior skill? On the other hand, if laborious investigation should lead to an opposite conclusion, there are many veterans of the profession still living, who, having been engaged on Jessop's great works in England and Ireland, have not ceased to regard him with a kind of religious awe, and who would point in triumph to many hundred miles of canal which he has successfully carried through great engineering difficulties, displaying superior skill in all the operations connected with earthwork, and ask, is it likely that he who has been so successful in works peculiarly and exclusively his own, could have perpetrated the blunders which some have ascribed to him on the Caledonian Canal? My own opinion, derived from the information of several gentlemen whom I have consulted, as being the most impartial of those possessing any knowledge on the subject, is this, that although Mr. Jessop did originally design the works, and settle the principal points, yet in the execution of these works, which were afterwards much varied from the original intentions, these two engineers are entitled to share alike in all the merits and defects which belong to them. It will add to the weight of this opinion to state, that it coincides with that of Mr. George May, of Inverness, the present talented engineer of the Caledonian Canal Commissioners. In the particular case relating to the lining of the canal with puddle, it seems probable, although Mr. Jessop first decided on the expediency of adopting it, that the two engineers afterwards considered it might be dispensed with, in consequence of the inexhaustible supply of water afforded by Loch Ness, the summit level of the canal. Some of the most porous parts of the canal ran alongside the river Ness, which seems to have been intended to receive any leakage that might take place, whilst it was further imagined that silt brought down from the Lochs would be deposited in the porous reaches of the canal in such quantities as to fill up the interstices, and render the whole water-tight. It is scarcely necessary to say that these expectations were not realized, that the canal at first would not hold water at all, and that although puddling has since been partially adopted, the original neglect of the precaution, leading as it did to the construction of the canal on too small a scale to receive the puddle lining afterwards, has been one main cause of the want of water, and consequent ill success which has attended the canal ever since the day it was opened.

The Caledonian Canal, being a government work, is so well known through the medium of parliamentary documents, as scarcely to require any general description. This grand communication was first proposed in 1773, at which time it was examined by the celebrated James Watt, for the commissioners of certain forfeited estates in the Highlands. The line was again surveyed, both by Jessop and Telford, in 1802, and the works were commenced in the following year. The whole length of the navigation, from sea to sea, is sixty miles, of which thirty-seven miles are occupied by the three inland lakes called Loch Ness, Loch Oich, and Loch Lochy, and the remaining twenty-three miles consist of artificial canal. The navigation being intended to admit frigates of thirty-two guns, as well as the largest class of vessels in the Baltic trade, and West Indiamen of an average size, was to have been formed with a breadth at top-water of 120 feet, bottom width of fifty feet, and depth of twenty feet. In place of this there are many parts where, in dry seasons, the depth does not exceed ten or eleven feet, so that an additional depth of more than five feet is necessary to adapt the canal for any thing like its original intentions. There are twenty-eight locks, on a scale of great magnitude, being each not less than 170 feet long and forty feet wide. The canal was opened in 1822, but works were in progress, under Mr. Telford's directions, for several years afterwards. The last parliamentary grant was made in 1824, the canal being still left in a very unfinished state, with a very insufficient depth of water.

It is understood that government is now about to advance a sum of nearly £144,000, for the purpose of adapting the canal to receive vessels of thirty-eight feet beam, and seventeen feet draught of water.

SURREY IRON RAILWAYS.

These consist of a double tramroad from the Thames at Wandsworth to the town of Croydon, with an extension from Croydon to Godstone and Merstham. They were executed by two separate companies, under the authority of four Acts of Parliament, obtained between the years 1801 and 1806. They were intended to facilitate the trade of the numerous valuable mills and manufactories on the river Wandle, which flows in the same direction as the line between Croydon and Wandsworth, the conveyance of fullers' earth, lime, firestone, chalk, and flints, from the quarries of Godstone and Merstham, and for the import of coals and manures into a district possessing no species of navigable communication. Mr. Jessop was intrusted with the execution of both these lines, which are principally remarkable as being the first public railroads constructed in the south of England. In addition to the construction

of the railway, which is laid out with an almost uniform inclination of 1 in 120 all the way from Wandsworth to Godstone and Merstham, a length of about 26 miles, Mr. Jessop formed a basin at Wandsworth capable of containing 30 barges, with an entrance lock into the Thames. The usual width of land taken for the road was about 24 feet. The rails were of cast iron, of the old plate form, with a raised flange on the inside. The width of each track was $5\frac{1}{2}$ feet. The waggons used were chiefly cast iron, with very narrow wheels, which consequently cut through and destroyed the rails in a very short time. The Wandsworth and Croydon line passing in the valley of the Wandle through a very flat country, has no cutting or embanking of any consequence, the principal works being bridges at the various crossings of the river Wandle. This part of the line, with its branches, is about ten miles in length. Mr. Jessop's original estimate was £33,000. Its actual cost, including, it is believed, some works which were not originally contemplated, has been about £60,000.

The line from Croydon to Godstone and Merstham passes across the chalk downs, in a valley called Smitham Bottom, nearly in the line of the present London and Brighton Railway. Opposite the Red Lion in Smitham Bottom, the line is carried on an embankment about twenty feet high, and a brick bridge carries it across the road to Epsom. Near Merstham there is a cutting, which for some distance is thirty feet in depth, and there are besides several short cuttings through projecting tongues of land, which the line encounters in its winding course through the valley. The original estimate for this work was £52,347, of which £35,800 was subscribed before going to Parliament. Its actual cost was nearly £90,000. Notwithstanding the very sanguine expectations which were at first entertained as to the success of these tramroads, it was soon found that they were never likely to realize much profit. The Brighton Railway decisively removed all chance of remuneration to the subscribers, and they accordingly acceded to the proposals of the Railway Company to buy from them the whole stock of the tramroad, consisting principally of its stone blocks and iron. The Brighton Railway Company thus became the proprietors of all the Surrey tramroads, and within a very recent period they have dismantled both lines of rails, and sold off the stone blocks and the rails on all that part of the road south of Croydon. I am not aware whether the whole of the line is yet broken up between Wandsworth and Croydon, or whether part of this is allowed to remain till the completion of the projected railway from Croydon to Vauxhall.

BRISTOL DOCKS.

The improvements executed by Mr. Jessop at the port of Bristol, deservedly rank among the greatest, the most beneficial, and most important of his works. Their principal object was the conversion of the river Avon into an immense floating dock, upwards of seventy acres in extent, and capable of accommodating 1400 vessels. The geographical circumstances of Bristol were peculiarly favourable to a work of this kind, which, in that situation, presented many advantages over the principle adopted in London, of excavating separate docks distinct from the river. Bristol is situated on the banks of the Avon, at the point where this river is joined by the Frome, and the city occupies all the angles made by the junction of the two rivers, and all the bends of their sinuous course. Although the Frome is much the smaller river of the two, yet the principal quay of the city had always been on its bank, and as the tide rose in both rivers to the height of forty feet, it was desirable that any plan for converting the rivers into a floating dock should embrace the point of junction, so that at least the water in the Frome should be dammed up, whatever became of the largest river.

Accordingly, in Mr. Smeaton's plan of 1765, we find that he proposed to cut a short canal, 750 yards in length, from a bend in the Avon up to the mouth of the Frome, to make a basin and entrance lock at the junction of the canal with the Avon, and to block up the mouth of the Frome, so that its waters would communicate with the river only through the canal, which was to be made wide enough to answer as a dock. The effect of this plan would have been to confine the extent of the floating basin to the canal and the river Frome, as no part of the Avon would be dammed up. The execution of this work, including the lock chambers, sluices, and dam, is estimated by Mr. Smeaton at £25,000.

About the same time, a Mr. Champion, of Bristol, proposed a plan for making a weir across the Avon, about a mile and a quarter below the junction of the Frome; this weir to have arches provided with sluices, with a great lock chamber for the admission of vessels, and a much smaller one for boats. This plan was not acted upon, and it was reserved for Mr. Jessop, about forty years afterwards, to devise and execute a far more extensive measure than had been before proposed.

Mr. Jessop's plan embraced the entire diversion of the river Avon for more than two miles, and the formation of a new canal to carry off its waters at the back of the city. By means of this great work, a length of nearly three miles in the rivers Avon and Frome has been converted into a wet dock, containing at all times an ample depth of water. Besides a dam at the east or upstream end of the new cut, and an overflow at the lower end, the works executed here by Mr. Jessop include an entrance basin

with double lock chambers opening into the Avon below, and a single chamber opening into the dock or old river above. This entrance is called Cumberland Basin. In addition to this, there is Bathurst Basin, with its locks opening from the floating dock into the new river course, nearly opposite the junction of the Frome; while at the upper end of the new cut another communication, between the new river and the floating basin, is effected by means of Calcraft Lock. Mr. Jessop also built over the new river two elegant iron bridges, which justly rank among the finest specimens of this style of building.

These extensive works were principally executed between the years 1803 to 1808, at a cost of about £317,000.

These are not by any means the whole of the works in which Mr. Jessop was engaged during the active period of his career, which is comprised between the years 1788 and 1805.

During this and the following years of his life, he was consulted on almost every canal, railroad, and harbour that was projected in any part of the kingdom. He was the great authority in support of that important, though unsuccessful, line of canal, between Newcastle and Carlisle, which is noticed at length in the Life of Chapman. In 1803, he surveyed a line of railroad from Portsmouth to London, the proposed terminus being on the side of the river Thames at Stamford Street. This railroad, the estimate for which was £400,000, was a rival project of Mr. Rennie's Portsmouth and Croydon Canal, but neither of these undertakings met with the support necessary for its successful prosecution. Mr. Jessop was extensively consulted on the numerous harbours of this country, and reported with great ability on the harbours of Shoreham, Littlehampton, and other places on the south coast.

If this truly great engineer was less employed in the actual execution of large works during the last few years than during a former period of his active life, it was only because the speculative spirit of that day had been in some degree exhausted, and works of magnitude had become less frequent; because, in fact, the country had then been profusely intersected by canals, and there were few sites left for the prosecution of further enterprise in that department of engineering.

On the successful completion of the greater part of the works which have been described, he became, not less than Smeaton had done before him, the great standing counsel of his profession, and was consulted not only by most of the private Companies who had undertaken engineering works, but by the Admiralty and other important public bodies, amongst whom his opinion was valued as it deserved, in proportion to the extent of his vast and varied practical experience.

Undoubtedly he effected much for the inland navigation of this country; and difficult as it is to trace the invention and first application of great practical discoveries, it is only justice to acknowledge that he first pointed out the practicability of supplying canals by means of artificial reservoirs in tracts which afford no natural streams of sufficient magnitude for the purpose.

That accurate observation of physical facts, which led to this and similar important results, is exhibited in one of his reports, which has been already quoted from, in which he remarks on the different quantities of water yielded by clay districts in dry and wet seasons. The immense floods to which such districts are subject at certain seasons, afforded him vast supplies of water which, with great skill and judgment, he stored up for the gradual and regular supply of his canals. While this important feature in the economy of inland navigation exclusively originated with himself, there are some other inventions of less importance with which he shares the chief honour of original application with Mr. Telford. Such was the introduction of iron for the troughs of aqueducts, and for the heads, heel-posts, and ribs of lock gates, as adopted on the Caledonian and Ellesmere canals.

Mr. Jessop died in the year 1814, having latterly suffered much from paralysis.

[The Author of this paper and the Publisher consider it necessary to state, that although they have not derived from the immediate relatives of the late Mr. Jessop any of that assistance which they ventured to expect, yet their thanks are eminently due to several valued friends of the author who had the happiness of personal intercourse with that distinguished engineer, and who have furnished them with numerous particulars, and allowed access to documents, the existence of which must be known to very few, and which would probably have never seen the light, but from the zeal which has actuated the Publisher in the production of these biographies.]

ON
THE UTILITY AND CONSTRUCTION
OF THE
DREDGING MACHINE.

IN the first or preceding part of this Journal, a paper is exclusively devoted to an investigation in favour of the person to whom the merit is due for the introduction of the dredging machine, to purposes of hydraulic engineering. It also contains some remarks on the construction and application of machines to like purposes at a very early period, tending to exhibit the various steps of improvement connected therewith up to the year 1808, when a machine of six horses' power was constructed under the direction of Mr. Rennie, for the excavation of the docks and river at Hull. There are also designs and descriptions annexed of a similar machine, for the purpose of clearing away, and also preventing the accumulation of mud in the docks at Blackwall. These preliminaries being stated by way of introduction, what now remains is to exhibit a few advantageous results, which otherwise could not have been so efficiently attained but through the medium of the dredging machine, with approved plans and specifications of such machines as are best adapted to the various situations in which they are most frequently required.

The dredging machine, since the application of steam power, has sufficiently proved, in many parts of the world, the most efficient expedient towards the advancement of commerce and commercial interests, not only as the means by which accumulated obstructions have been removed, but also as the means by which rivers have been enlarged to a sufficient extent for the transit of commodities by navigable means; but to enumerate all of even the most conspicuous of those places that have thus been benefited, would much exceed my present assigned limits, and not materially, that I am

aware of, as regards the present purpose, add to any important advantage ;—however, as reference may be required by individuals for farther information, a few places shall be named at which dredging machines have been, and are now, advantageously employed.

1. In the river Clyde to Glasgow, dredging machines have been and continue to be extensively employed, and the merits of the great improvements in that river are entirely due to their successful operations. At the time when the value of steam, as a moving power, began to be appreciated by parties interested in navigation, the river Clyde could offer but small inducement to enterprising speculators, on account of its extremely contracted breadth, and the want of sufficient depth of water to admit vessels with an advantageous cargo up to the Broomielaw ; but the wealthy amongst the citizens of Glasgow, foreseeing, as it were, the vast benefits which now accrue from the application, immediately raised a capital sufficient for the widening and deepening of the river to a proper extent ; the aid of the steam dredging machine was brought into action ; and now, from a river insufficient for vessels of more than 50 tons' burthen some forty years ago, is now daily traversed by vessels from 600 to 700 ; and Glasgow, through this means, raised in estimation as one of the first commercial cities in the world. As a comparison of its accumulation of wealth in a few years after the river being rendered properly navigable, namely, from 1826 to 1843, the harbour and tonnage dues have regularly increased from £16,200 to £42,201 per year. And this augmentation of revenue has no doubt acted as a stimulus to farther improvements, as during the two last summers, not less than 160,000 cubic yards of a partially obstructing bank have been entirely removed from the bed of the river, by these still continued exertions, accompanied with the advantageous workings of the dredging machine.

2. Dublin may next be noticed as having benefited much by the operations of the dredging machine, and not until lately could any vessel worthy of a foreign cargo attempt going into the river Liffey, on account of the bar and number of sand banks ; and in consequence of which the export and import of goods or produce, to and from foreign parts, were compelled to be had through the intervention of the Liverpool and Glasgow speculators ; but now that those obstacles have in a great measure been cleared away, the Irish merchants can employ their own vessels—send or receive in a direct manner, avoiding the liability of inconvenience and expense that are ever likely to occur in purchasing through a second hand ; and at this present time there are not less than twenty vessels lying in the river, and at the various wharfs, discharging products of different kinds direct from foreign countries.

3. The trade and wealth of Belfast and Drogheda have also been greatly ex-

tended by the deepening of their rivers, and thence the introduction of steam navigation, but, indeed, previous to the operation of excavating by the power of steam, and the introduction of steam vessels, when a sufficient depth of water was attained, those places, and many others that are now in a considerable state of affluence, were, in a commercial point of view, seldom or never spoken of.

4. The agency of the dredging machine is likewise essentially advantageous to the interests of the shipping in the port of London; but certainly not so much in preventing the accumulation of mud into obstructive quantities in the river, as insuring an immediate supply of gravel for the ballasting of outward-bound vessels with light cargoes; and it is equally advantageous to contractors and others, by insuring a constant supply of a superior quality of sand for the purposes of building.

5. The immense quantities of matter carried in by every influx of the tide, and deposited in the extensive docks and basins for the shipping at Liverpool, render there the services of the dredging machine exceedingly valuable. In that port the aggregate water area of docks and basins is about 538,000 square yards, or 111 acres, and a considerable portion of that surface is covered by a deposit of several inches between every return of the tide, and although this be the case, only two dredging machines are required; viz., one of twenty horses' power with two sets of buckets, and one of twelve with one set, to keep the docks clear and at a uniform depth; and it is stated with confidence, from practical experience, that no other means hitherto tried, or at present known, could at all approximate to an equal quantity of material removed at an equal expense.

6. The dredging machine has also been the means of partially clearing away the banks of mud in the river Elbe at Hamburgh, but unfortunately only one machine has hitherto been, where two at least ought to be, employed. Previous, however, to its application there, vessels were very frequently detained for several days together, waiting for a sufficient depth of water to carry them up or down, clear of the banks in the river; and even now, for the want of the proper means being carried out to an efficient extent, vessels are obliged to make their way at considerable risk or hazard of getting aground, and through which depreciation of cargo is no uncommon consequence.

7. The properties of the dredging machine to effect similar purposes, are now begun to be appreciated in Turkey and in Egypt; various of which have of late been constructed and sent out from England, and are now in progress of erection at their several destinations, or probably by this time set to work and in active operation.

Other countries, many of which are much better situated for the cultivation of commerce; and that now have the opportunity of not only witnessing the strength,

wealth, and splendour to which various of the above named places have arisen; but also the means in a great measure by which those immense advantages have been attained; it will be certainly astonishing, if we do not, in the course of a short time, see the spirit of enterprise stirring up in, *for instance*, such well situated countries as Italy and Spain, where the proper facilities for commerce and competition are yet so much required.

With regard to the construction of dredging machines, they are both necessarily and optionally of various designs,—necessarily, because machines with two sets of buckets, or buckets on each side of the vessel, are not at all adapted to narrow rivers, on account of their unavoidable breadth and consequent obstruction;—and optionally, because the arrangement of the machinery is at the entire discretionary judgment of the constructor. Hence, with a view to render this paper equally serviceable to individuals, whether interested in harbour, dock, or river excavation, two different modifications of most approved machines are annexed, the one by Messrs. Summers, Groves, and Day, of Southampton, and the other by Messrs. Girdwood and Co., of Glasgow, and although they differ materially in design, are each equally efficient in their proper situations.

The best adapted boilers and engines for dredging purposes, are those upon the marine principle, as in them compactness and stability are combined; and for which reasons, they of that description are invariably applied; but in practice it is found disadvantageous to the profitable working of the machine, if the engine be not of a proportionate power to the depth of water, the buckets of a suitable number, and the bucket frame of sufficient length to lie at a proper angle. Hence the following arranged proportions are annexed as the best adapted for working at or about the various specified depths from which the material is to be raised:—

Nominal Power of Engine.	Length of Bucket Frame.	Number of Buckets.	Depth of Water in Feet.
20	59½	34	18
25	63	36	20
30	78¾	45	25

The Boat, or Barge, as it is frequently called, requires little or no peculiarity of form, otherwise than that of proper stability; it must be strong and well put together, or a constant tremulous motion is created by the action of the machinery, and the proper effect of the machine in a measure destroyed. It must also be of magnitude sufficient for the receiving of the machinery with a proper clearance for the buckets, according to the depth of water, and different positions in which, on that account, they are so frequently required.

That portion of the construction in which is required the greatest degree of attention, is the judicious selection and application of proper materials, also in the proper proportional exactitude of the parts of which the machinery is composed.

DESCRIPTION OF THE MACHINERY IN THE DREDGING VESSEL CONSTRUCTED BY SUMMERS, GROVES, AND DAY, MILL PLACE IRON WORKS, SOUTHAMPTON.

The objects which were chiefly kept in view in arranging the machinery of this dredging engine were simplicity of construction with efficiency and facility in adapting it to the work it would have to perform, and after some consideration, it appeared to the makers, that a marine steam engine, with side beams, was the best kind of engine for this purpose; as it enabled them to convey motion to the buckets with less wheel-work, shafting and machinery than is generally required in dredging engines, whose works are frequently complex, and require considerable skill in their management.

PLATES IV. V. VI. VII. VIII. AND IX.

SHOW AN ELEVATION, PLAN AND SECTION OF THE VESSEL AND MACHINERY.

a. Is the boiler constructed with internal fire-places and flues similar to boilers commonly used for marine engines. *b.* Steam pipe leading from the steam chest on the boiler to the engine. *c.* Is a condensing engine of 20 horses' power, the cylinder being 27 inches diameter, and the length of stroke of piston 2 feet 9 inches. The engine is constructed with side beams on the marine principle, and the motion is communicated to the fly-wheel shaft *d*, by a connecting rod in the usual way. *e.* Is the fly-wheel. *p.* Is a friction hoop, which fits lightly round a drum or sheave keyed fast on to the fly-wheel shaft. The use of this contrivance being to prevent accidents to the machinery, in case the buckets should get entangled with any thing during the process of dredging, as when the resistance increases beyond what is necessary for raising the soil, the drum or sheave slips round inside the hoop, and the buckets cease to work, whilst at the same time the steam engine may continue its motion without injuring the machinery. *g.* Is a pinion bored to fit the fly-wheel shaft, (but not keyed fast to it,) having two strong stops or carries cast on one side of it, which come in contact with corresponding stops on the wrought iron ring or hoop. *h.* Is a spur-wheel, which is driven by the pinion *g*. *i.* Is a pinion keyed on the intermediate shaft, which drives the spur-wheel *j*, keyed on the tumbler shaft. *ll.* Are clutch couplings for the purpose of connecting one or both sets of buckets to the steam engine, or disengaging them when required. *m m m m.* Are cast iron carriages, forming joints or hinges for supporting the bucket ladders independent of the tumbler shafts. *n n n n.* Are the tumblers over which the chain and buckets work. *qqqq, &c.* Are the buckets made of

boiler plate and bolted securely to the links of the chain in a peculiar way, more clearly described in Plate VIII., where the buckets and links are shown on an enlarged scale, and in which, on the front of the buckets will be observed a kind of spade that is of steel, and attached to the bucket by rivets, consequently easily renewed at any time when worn away;—the bucket chain runs on cast iron rollers *pp*. The bucket ladders are made partly of wood, having wooden sides with cast iron king posts, and transverse trusses; with wooden struts and wrought iron tie bolts with screws at the ends, so that they may be tightened up when required. These ladders are remarkably strong with comparatively light materials.

The spout *g* is of wood lined with sheet iron, and has a joint at *r* to allow of the punts or barges being equally loaded on both sides without turning them round. As when the outer end of the spout is raised by means of the purchase *z*, the soil will escape at *r*, near to that side of the barge which is close to the dredging machine; on lowering down the outer end of the spout, the soil will be carried over to the other side of the barge, thus ensuring its being equally loaded. The bevel wheels *tttttt* and shafts *uuu*, Plates V. and VI., convey the motion from the steam engine to the apparatus on deck for propelling the vessel to and fro, raising or lowering the bucket ladders, &c. The ladders are raised by chains, passing round the barrels *vv*, and working in the sheaved blocks *bb*, which are suspended from the timber framing. The operation of raising the ladders is effected by connecting the barrels to the shafts by the clutches *ww*, which are worked to and fro by levers that pass through the deck of the vessel: when the ladders require lowering the clutches are drawn back and the ladders run down of themselves to any depth which is desired, being regulated by a brake attached to the drums at *xx*, as shown in Plates V. and VII.

The apparatus for propelling the vessel to and fro is fixed on the deck. *yy*. Are two curved cast iron barrels. By taking two or three turns of a rope or chain round these barrels, one under and the other over, one of the ropes will draw the vessel ahead, whilst the other pays off the slack, and vice versâ; or by putting both ropes or chains the same way round these barrels, they will both act in pulling the vessel in the same direction. It should be named that there is a friction sheave placed between the propelling machinery and the steam engine, similar to that which is fixed upon the fly-wheel shaft, to prevent the chains or ropes being broken in case of any obstructions.

BUCKET LADDER. PLATE IV.

The ladder is composed *partly* of timber framing; the main timber *m* (which runs the whole length) being eighteen inches deep, and eight inches broad, connected by strong cast iron crosses, (*not* shewn in the drawing, as it was thought they would only

confuse the adjacent parts.) To give it strength to bear the weight of the buckets with their contents, it is furnished with a cast iron king post *k*, having two inch tie-bolts *s s* connected to its lower extremity by a single and double forked joint, through which joints and the king post a pin passes, thus firmly uniting them at this point; the *other* ends of the tie-bolts pass through snugs, cast on the top and bottom carriages at ends of ladder, and are furnished with a screw for the purpose of setting them up, by means of a nut, should they at any time become slack. There are also two *wooden* trusses *w w*, which take the strain of the framing, midway between its centre and either end. This ladder is found sufficiently strong, and well adapted for sustaining a heavy weight; at the same time it is extremely light in appearance.

BUCKETS, ETC., IN DETAIL. PLATE VIII.

The buckets are made of boiler plate, the back being half an inch thick. The back plate rises considerably above the other parts of the bucket, and slopes forward at an angle of about 25° towards the front or lip of bucket, for the purpose of retaining the soil, and preventing its being spilled during its progress, after receiving it from the excavation, until it deposits the same in the barges alongside. The form of this back plate prevents a great loss of mud or other material, which would otherwise be the result, and consequently a loss of time would follow, and the quantity of soil delivered would not be adequate to the power of the steam engine. All the other parts of bucket, (exclusive of the back plate before mentioned,) are three eighths of an inch thick. The buckets at present dig to a depth of twenty-four feet, but greater depths may be obtained by merely lengthening the timber framing of ladder, and adding a greater number of buckets and links, proportionate to the extended length.

BUCKET LINKS.

As the bucket links, or chains (as *before* called) are given in the same drawing with the bucket, further description is deemed superfluous; it may, however, be remarked, before leaving the subject, that the links pass over the tumblers with perfect ease, and *without noise*, (which *latter* quality is a great desideratum in machinery of this description,) owing to there being no projections on their *lower* sides, as the requisite strength round the pins is carried *above* the centre of the link, and not on *each side*, as is frequently the case.

SHAFTS AND FRAMING. PLATE VI.

The upper or tumbler shaft *s s s*, is in three lengths, having *two* coupling boxes *ll*, fitted to them, for the purpose of working either *one* set of buckets or *two* sets

simultaneously ; the bearings or journals of the shafts are four in number, seven inches in diameter and nine inches in length, and working in plummer blocks, resting on four timber frames *ffff*. The intermediate or middle shaft *ii*, has bearings five inches and three quarters diameter and eight inches in length, working also in plummer blocks which rest on wooden framing *ff*; and the lower or fly-wheel shaft *d*, has bearings five inches and three-quarters diameter and eight inches in length, one bearing of which rests on the engine frame, and the other on the timber framing. These timber frames are severally connected at their tops by a strong transverse beam *tt*, twenty inches deep and eighteen inches broad, the *outer* ends of which support carriages (to be hereafter described) for carrying the ladders, &c. By this arrangement, and by being securely fastened at their bases, the four upright timber frames are firmly kept in their perpendicular position. The form of these frames will be clearly understood by reference to the elevation, Plate IV.

OUTER OR HANGING CARRIAGES. PLATE VI.

It will be seen that the outer or hanging carriages (mentioned in the preceding paragraph, and marked in the drawing) *mm*, are connected to the ends of the transverse beam in rather a novel manner : the hanging part, or part *beneath* the beam being attached to the cap or top plate by means of twelve one inch and a quarter bolts, by which method it can be securely fastened to the before-mentioned beam, and adjusted so as to accommodate the tumbler shaft, by means of packings being introduced between the cap and top of timber, and which can easily be removed at any time when required.

TUMBLERS. PLATE IX.

This Plate consists of a detailed plan and section of top and bottom tumblers ; they being of essential consequence to the efficient working of the machine, are therefore minutely delineated in an extended scale, thereby rendering the design more easily understood than by a lengthened description, which it would otherwise require. It may be observed, however, that they are of cast iron, and the corners only being liable to derangement, are separate pieces, consequently easily removed when required.

This engine with its machinery is capable of raising and *has raised* 160 tons of soil per hour, upon an average, *one* set of buckets only having been employed in the performance, with a weight of three pounds and a half per square inch upon the safety valve of the boiler.

It may be remarked, in conclusion, that the boat is supplied with a bilge pump for discharging the bilge water, and a deck winch for moving the boat *by hand* when the engine is *not* working. The chain for raising the lower end of the ladder, (the *method* of raising has been described,) is five eighths of an inch in diameter, of the description called "*short link*." The draught of water is three feet six inches, with *every thing on board*, and the bottom is perfectly flat, and *both* ends are of the same form.

SPECIFICATION FOR A DREDGING VESSEL OF THE FOLLOWING DIMENSIONS.

Length of deck	ft.	in.
Breadth, extreme	22	1
Depth in hold	5	4
Tonnage	169 $\frac{3}{4}$.	

THE SCANTLINGS AS FOLLOWS:—

Chine, American or English elm or beech	in.	by	in.
Floor timbers, American elm or birch	12	—	14
Kelson do.	9 $\frac{1}{2}$	—	10
Stems, English oak, sided 8 inches, moulded 9 inches.	12	—	11
Aprons, do. 8 inches, „ 8 „			
Timbers, do. 6 inches, head 6 „			
Stemson knee, at each end sided	7		
Deck beams, English oak, sided 7 $\frac{1}{2}$ moulded 8 $\frac{1}{2}$ „			
Deck knees do. „ 5			
1 deck hook do. at each end sided	9		
1 breast hook do. „	7 $\frac{1}{2}$		
Stancheons do. „	5		
Winch bits do. „	6 × 7 $\frac{1}{2}$		
Propelling gear bits, English oak	9 × 11 $\frac{1}{2}$		

PLANK:—

Bottom	3 $\frac{1}{2}$ inch English elm.
Outside	2 $\frac{1}{2}$ inch American elm.
Clamps	4 $\frac{1}{2}$ inch do.
Plank sheer	2 $\frac{1}{2}$ inch do.

Deck $2\frac{3}{4}$ inch yellow pine.
 Bulwark $1\frac{1}{2}$ inch do.
 Roughtree rail $4 \times 2\frac{1}{2}$ inch English oak.

IRON WORK:—

Butt bolts in bottom and sides $\frac{3}{4}$ inch.
 Stemson knees and breast hooks 1 inch.
 6 pair of iron knees in the wake of boiler and engine $\frac{3}{4}$ cwt., each
 fastened with 1 inch iron.

Deck, 5 inch spikes.

Deck fastenings all of iron.

The vessel to have both ends alike, with a break in the deck both fore and abaft.

The platform of 2 inch yellow pine round the boiler for the stowage of coals, and
 $1\frac{1}{2}$ inch yellow pine in the engine room and cabins.

DESCRIPTION AND SPECIFICATION OF A DREDGING MACHINE, CONSTRUCTED BY
 MESSRS. GIRDWOOD AND CO., OF GLASGOW, FOR THE EXCAVATION OF THE
 RIVER CLYDE.

Plates X. XI. and XII. exhibit an elevation, plan, and section of the engine and dredging apparatus, the letters of reference corresponding in each Plate or separate view of the design.

THE BOAT OR VESSEL.

The timbers of this vessel are all exactly similar in specified variety and dimensions to that by Messrs. Summers and Co., and, as already minutely detailed, need not here be again repeated, but the external dimensions of the vessel are a little different, and which are the following: entire length on deck 90 feet; extreme breadth 22 feet; height from ceiling to ceiling seven feet; and when all is on board and in complete working condition, the draught of water is about four feet. Six are the number of men employed on board.

THE BOILER, ENGINE, AND MACHINERY. PLATES X. AND XI.

A represents the boiler, and B the engine; both of which are of the usual construction adapted to marine purposes. The cylinder of the engine is 26 inches diameter; length of stroke $2\frac{1}{2}$ feet; number of strokes per minute 44; and requires about two cwt. of good coal per hour for the generating of a sufficient supply of steam. In effect, the engine will lift, from a depth of 18 feet, about 110 tons of mud

or clay per hour, or 160 tons of sand or gravel in the same time; but in very hard ground and intermixed with stones no proper data can be given. The vessel is moved forward by the power of the engine, through means of the bevel wheels, shafting, pitch-chain, &c., as shown in each design, and which communicates motion (when required) to, and by means of the double acting winch R, and when the buckets are working in mud or clay, the vessel is caused to advance at the rate of about four feet per minute, when in gravel or sand at $2\frac{1}{2}$ feet per minute, and the number of buckets delivered are 14 in that space of time.

With regard to the movement of the buckets, motion is given to the wheels c and D by the crank shaft s of the engine, and communicated by the line of shafting e, e, e, &c., to the wheels F and G, from thence to the buckets by the barrel or tumbler T, that being made fast upon the spindle I, which is of malleable iron, eight inches diameter, and on which the wheel G is fixed. The small wheel c is three feet three inches in diameter; the cog wheel D is seven feet diameter; the shafts e, e, &c. are of cast iron, $6\frac{1}{2}$ inches diameter in the bearings; the bevel pinion F is two feet three inches diameter, and the bevel wheel G is six feet, and makes seven revolutions per minute; the top or upper tumbler T has four sides, and the bottom tumbler V five; as when they are thus formed, the motion of the buckets are found in practice to work more steady, and, consequently, the effects rendered more complete.

The bucket frame H, acting upon I as a centre, is also regulated to a proper depth of water by the power of the engine; the bevel wheel K upon the crank shaft s gives motion by means of the wheels l, m, n, to the barrel r, and round which the chain of the tackle passes, as shown distinctly in the elevation.

The wheels K and l are each two feet four inches diameter; the pinion m on the bottom of the shaft t is 10 inches diameter, and the wheel n four feet two inches. On the same shaft with the bevel wheel n is fixed a spur pinion g, of one foot seven inches diameter, which gives motion to the wheel o, of three feet three inches; the motion is communicated (when required) by means of the clutch c, c, and, when the frame H is raised to a sufficient height, and placed at the requisite depth of water, farther motion of the barrel is prevented through disengaging the clutch by means of the lever w, and the barrel rendered stationary by the lever and friction pulley y, y. The clutch is two feet four inches diameter; the friction pulley is three feet eight inches diameter, and its breadth of strap $3\frac{1}{2}$ inches. The length of the chain barrel r is $4\frac{1}{2}$ feet, and its diameter two feet. The shaft t is $4\frac{3}{4}$ inches diameter, and the barrel shaft $5\frac{1}{2}$ inches, each being of cast iron.

The following are the number of teeth that each of the preceding named wheels contain, also the pitch and breadth upon the face:

c 2

Wheel or Pinion.	Number of Teeth.	Pitch.	Breadth.
Spur pinion on crank shaft <i>c</i> . . .	49 . . .	$2\frac{1}{2}$ in. . .	$8\frac{1}{2}$ in.
Cog wheel on end of laying shaft <i>d</i> . . .	112 . . .	$2\frac{1}{2}$. . .	$8\frac{1}{2}$
Bevel pinion, marked <i>F</i> . . .	27 . . .	$3\frac{1}{8}$. . .	8
Bevel wheel <i>G</i> . . .	72 . . .	$3\frac{1}{2}$. . .	8
Mitre wheels <i>K</i> and <i>l</i> . . .	44 . . .	2 . . .	$4\frac{1}{2}$
Bevel pinion <i>m</i> . . .	15 . . .	$2\frac{1}{8}$. . .	$4\frac{1}{2}$
Bevel wheel <i>n</i> . . .	75 . . .	$2\frac{1}{8}$. . .	$4\frac{1}{2}$
Spur pinion <i>g</i> on shaft with <i>u</i> . . .	35 . . .	$2\frac{3}{8}$. . .	5
Spur wheel <i>o</i> on chain barrel shaft . . .	51 . . .	$2\frac{3}{8}$. . .	5

THE BUCKET FRAME, BUCKETS, LINKS, ETC.

The bucket frame is of the best red pine strongly trussed and strapped with iron, and in form and dimensions similar to the bucket frame already described in the preceding machine; in length it is 55 feet 4 inches, and the number of buckets thirty-four, each bucket being $26\frac{1}{2}$ inches wide, 16 inches broad, 17 inches deep, and formed of the best plate-iron $\frac{3}{8}$ inch in thickness; on the back or sole plate *p*, of each bucket, and immediately beyond its formation, is an attached piece or continuation of the plate, so as to form a covering to the joints of the links, and so prevent any injurious effects from the constant liability of contact with the excavated materials; also on the front of the buckets are fixed pieces of iron shod or edged with steel, for the purpose of increasing the strength of that portion of the bucket, and the better adapting of the same for coming in contact with hard materials, likewise that of being easily removed when required for repair.

The links *x x x*, &c., that connect the buckets are of wrought iron, each link being 21 inches from centre to centre of joint; flanges are formed on the double links, as shown in the design, $2\frac{1}{4}$ by $\frac{7}{8}$ ths of an inch, and to which the buckets are fixed by $\frac{7}{8}$ ths of an inch rivets; the diameter of the joints is $3\frac{3}{4}$ inches with $\frac{1}{4}$ inch projecting on each side, to increase the surface of bearing for the pins: all the joints and pins are cased with steel and properly hardened.

The rollers *r r r*, &c., are for the proper conducting of the buckets along the frame *H* and are of cast iron 8 inches in diameter, with axles or bearings of wrought iron, $1\frac{1}{2}$ inch diameter, and which revolve in cast iron receptacles or bushes. The ends of the tumblers also revolve in cast iron bushes, that metal being found more durable for this purpose, I understand, than any hitherto tried.

It may not be out of place here, as being through the means of the action of the buckets and bucket-frame, to remark an idea or system given by a Correspond-

ent in the "Civil Engineer and Architect's Journal," which he calls *radius cutting*, in distinction to that of the common practice called *trench cutting*, and I have no doubt in various instances must be of considerable advantage. In the ordinary method called *trench cutting*, the power applied to lead the machine ahead into the cutting, has also to resist the reaction of the buckets. Now, in *radius cutting*, the chain from the bow of the vessel is not wound up while it is cutting, but is only shortened at each return of the machine, and which causes a swinging motion of the vessel to take place; the machine being led laterally to the cutting by the side chains; and which are comparatively easy to work, as the reaction of the buckets is mostly against the *bow* or *radius* chain.

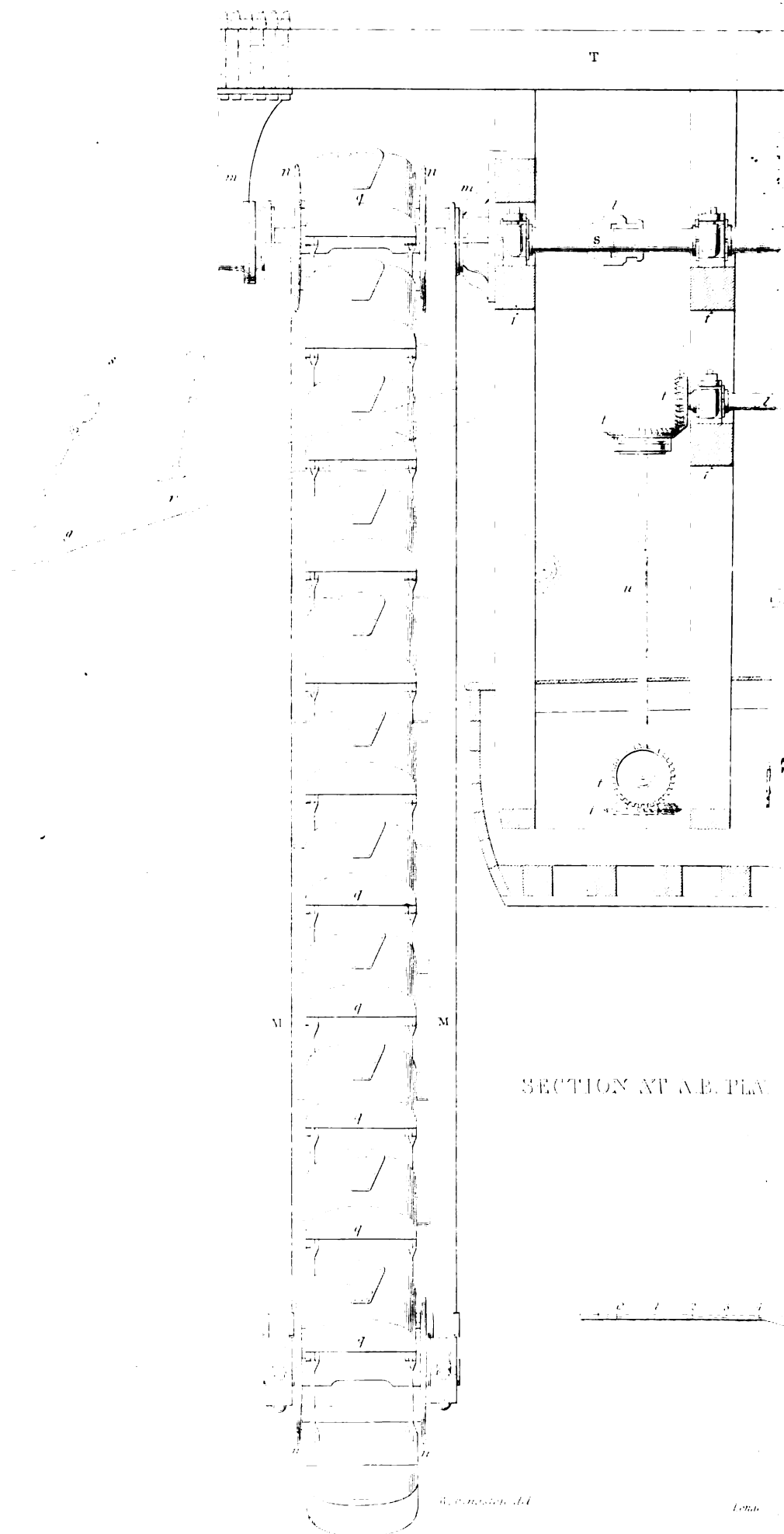
In respect to any inconvenience attending the use of these lateral chains, in a harbour or narrow navigation, it is no more than in the ordinary method, as corresponding chains are then required to keep the machine in line, and these are necessarily used on both sides at once; whereas, in the other system, these lateral chains are only tightened on one side—namely, that on which the machine may happen to be traversing; and where it is required to lower them, to allow vessels to pass, they only again require to be tightened up sufficiently to let the buckets fill.

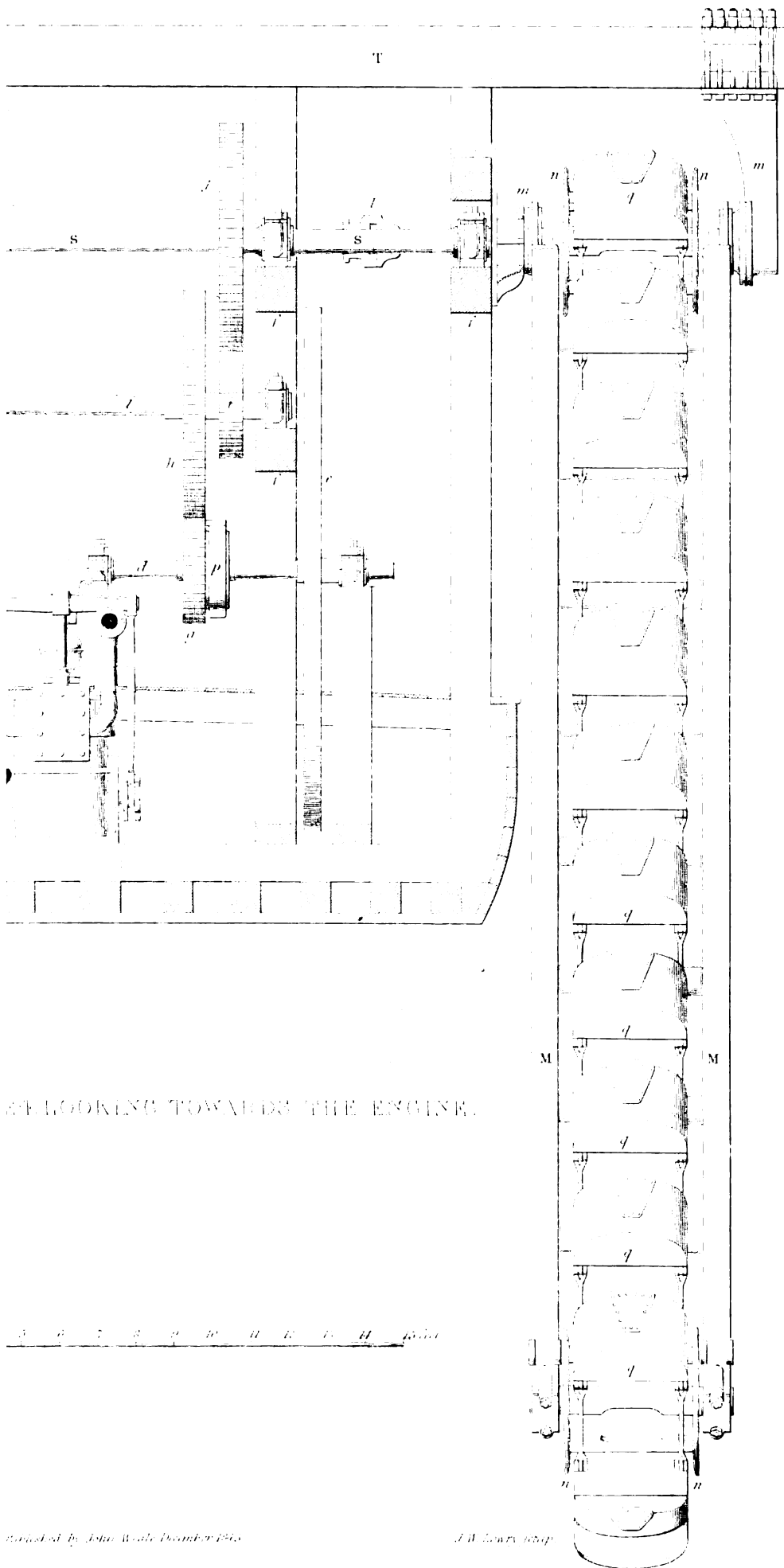
It may be contended that, to cut or trench a bank in the proper current, will, by changing the currents and eddies, remove it by a natural process; but, as this is a point so difficult to hit upon, it is generally allowed that, to get large stones and rocks taken up, and to cut the surface fair, is the surest way of reducing a bank, and of leaving it in the condition least liable to "silt up."

The difference of construction in the machine is trifling, so as to adapt it to the radius principle, being only the doing away with the flanges on the bottom tumbler, and substituting in their stead "snugs" on the tumbler between the chains or links, to prevent their getting off. But it must be borne in mind in the constructing of dredging machines for whatever kind of cutting, that a proper means be effected for preserving the chains employed in taking the vessel ahead, when the power of the engine is applied, and the best method that I am at present aware of is that of "conical friction."

THE PUNTS.

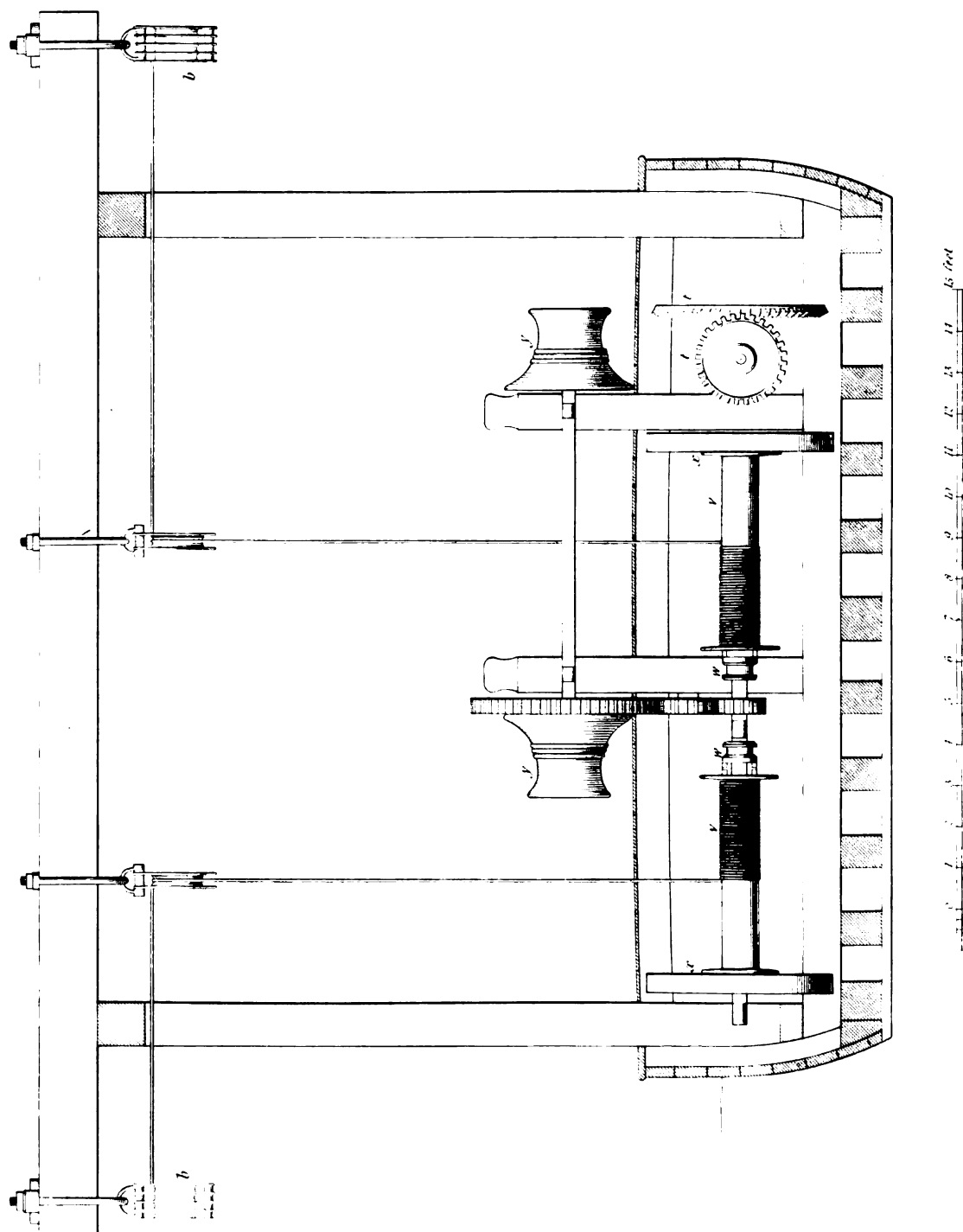
The excavated material from the dredging-machines on the river Clyde is carried away by punts, or large rectangular boxes of plate iron. In dimensions, they are each 32 feet in length, 14 in breadth, and 3 in depth; through the deck of which is an opening 27 feet 8 inches by 10 feet 4, and around this opening is a cooming 10 inches in height, as a prevention to the stuff getting over upon the deck; each punt carries on an average 20 to 22 tons, and a small steam-tug of 70 horses' power takes from 18 to 20 loaded punts at one time.





AT LOOKING TOWARDS THE ENGINE.

SECTION AT C, D. PLATE 4. LOOKING TOWARDS PROPELLING GEAR.



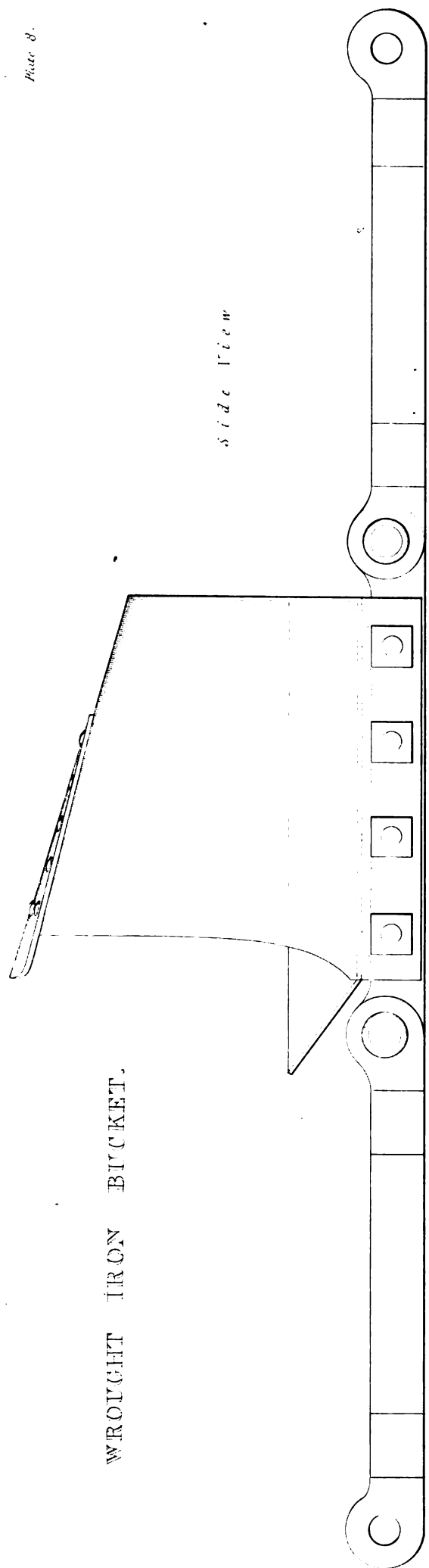
J. W. Lowry, Esq.

London: Published by John W. Lowry, 1843.

W. Simpson, del.

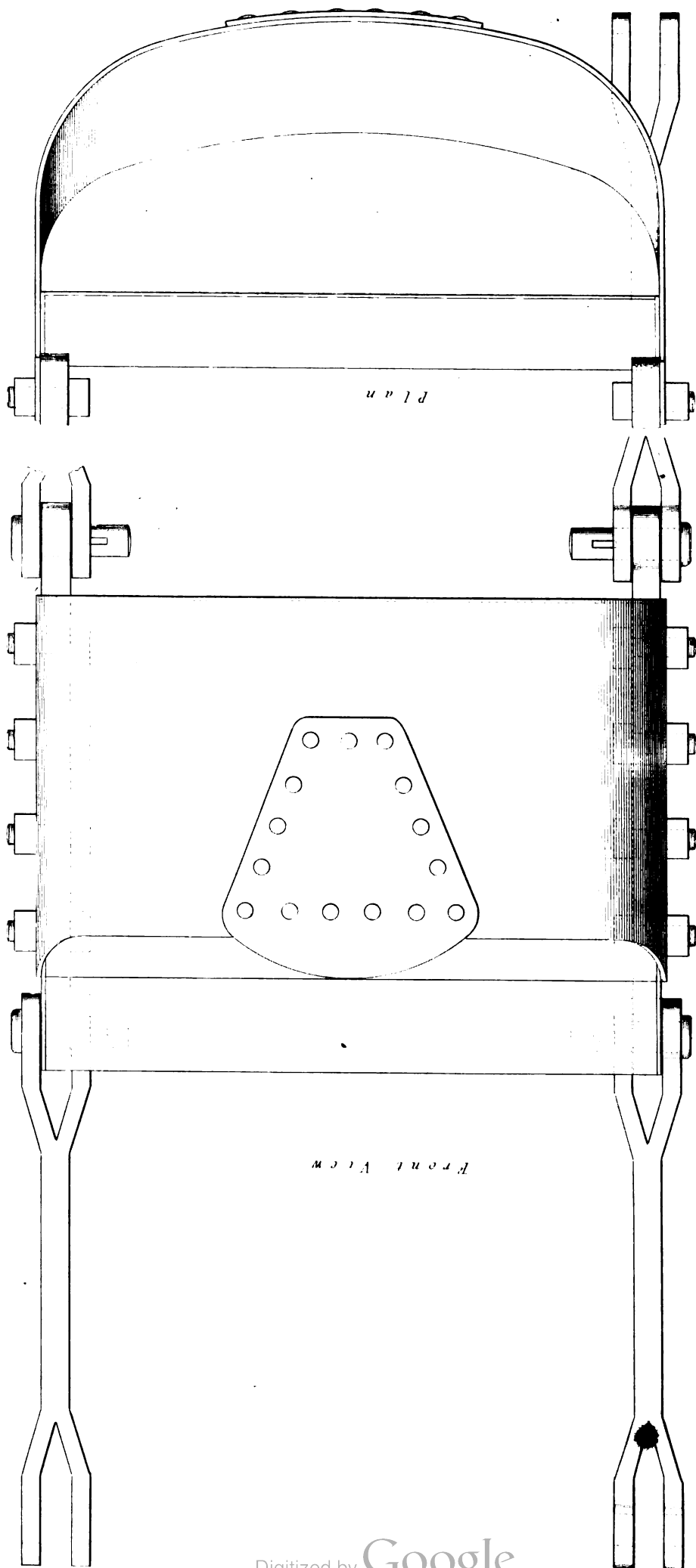
WROUGHT IRON BUCKET.

Side View



inches 12 10 8 6 4 2 0 8 feet

Front View



Plan

2nd Lower View

London Published by John Wade December 1853

Fig. 3.

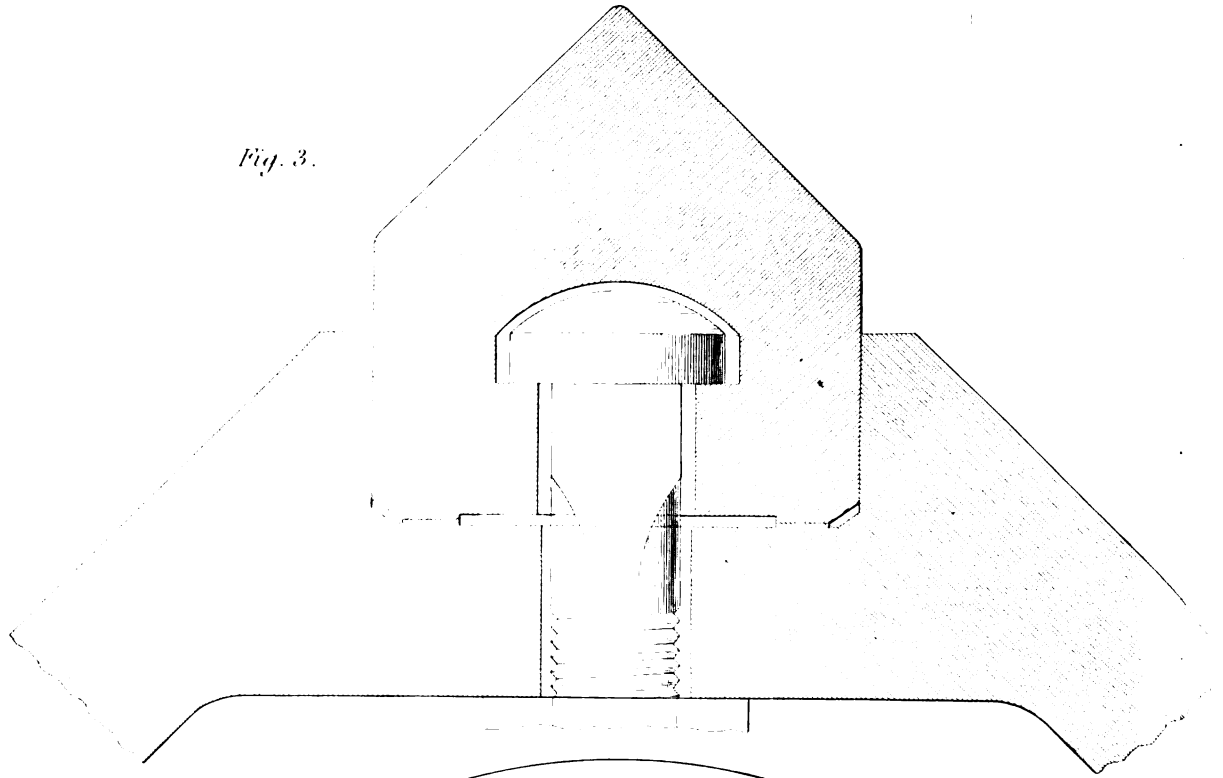
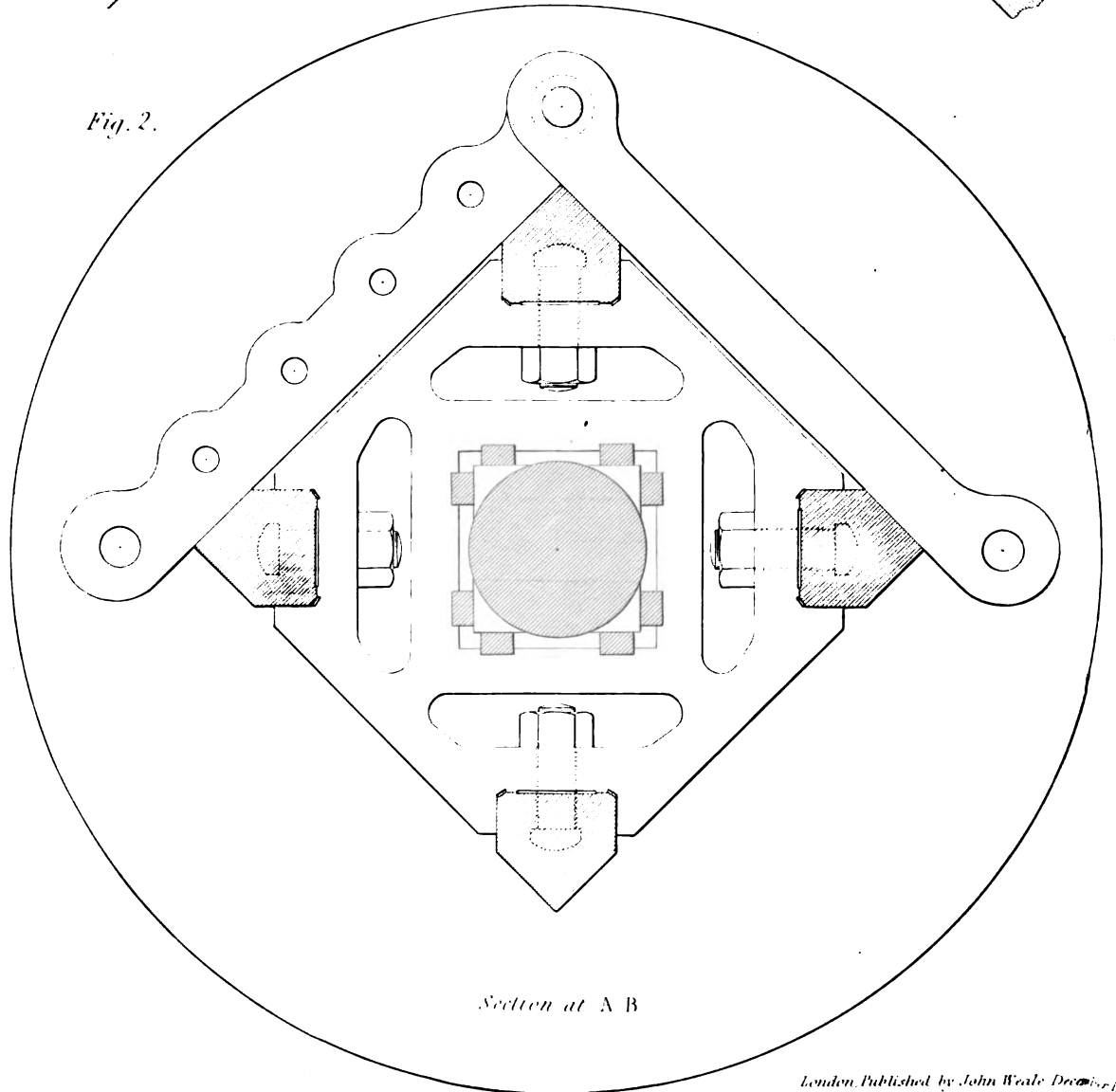


Fig. 2.



Section at A B

London, Published by John Weale, Decr 1843

TUMBLER.

Scale to Fig. 3.



Scale to Figs. 1 & 2.

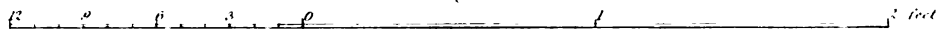
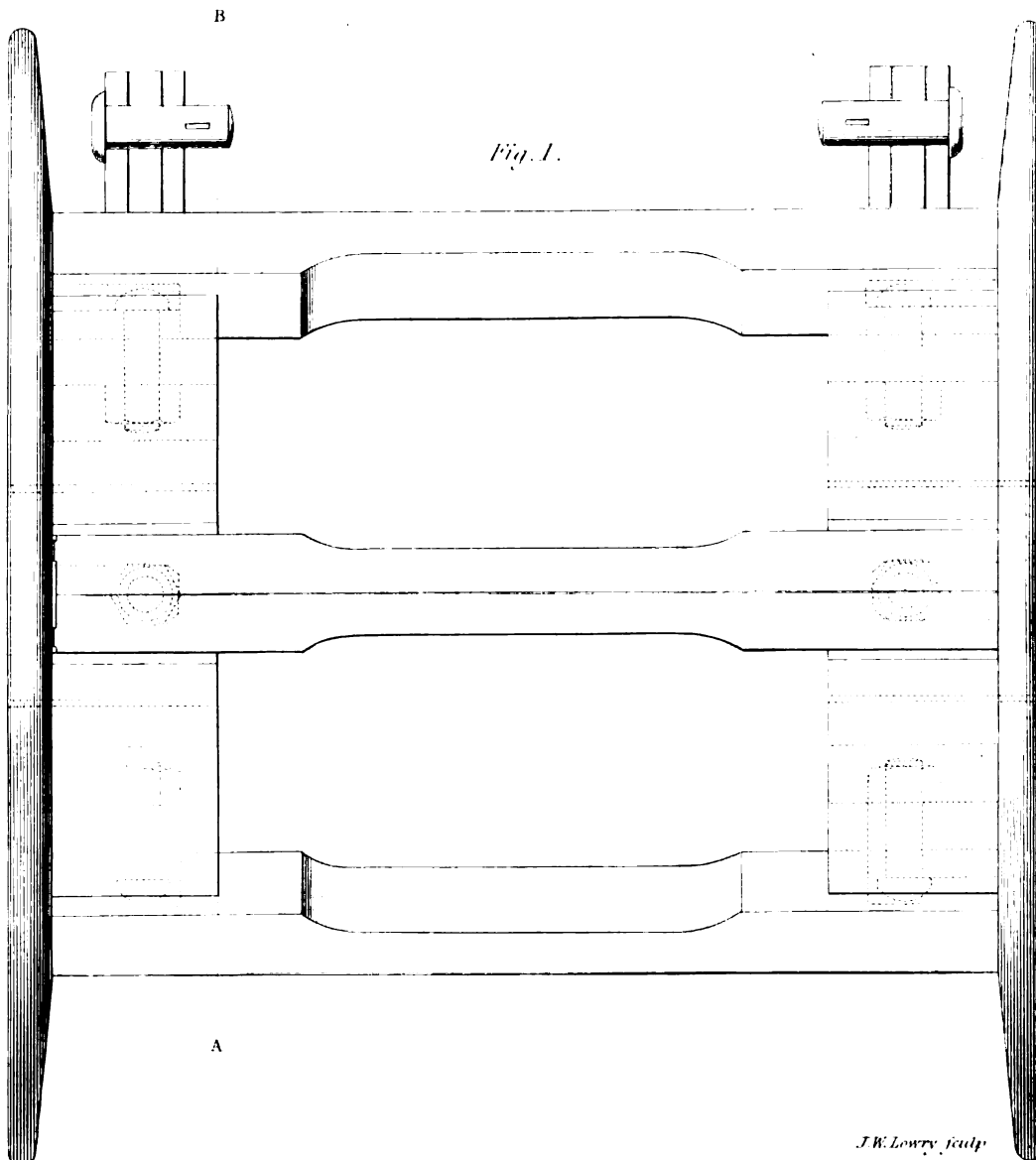


Fig. 1.

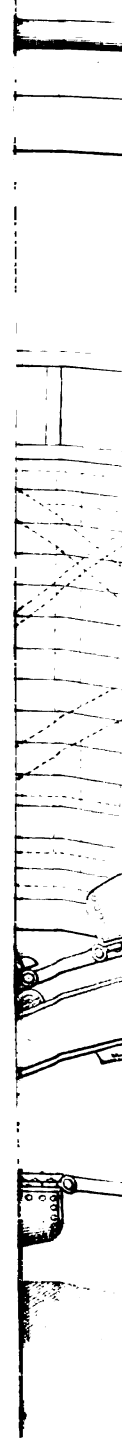


London, Published by John W. & Co. December 1848.

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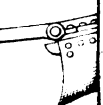
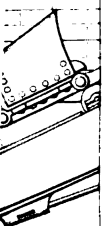
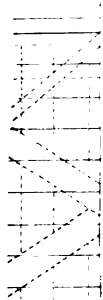
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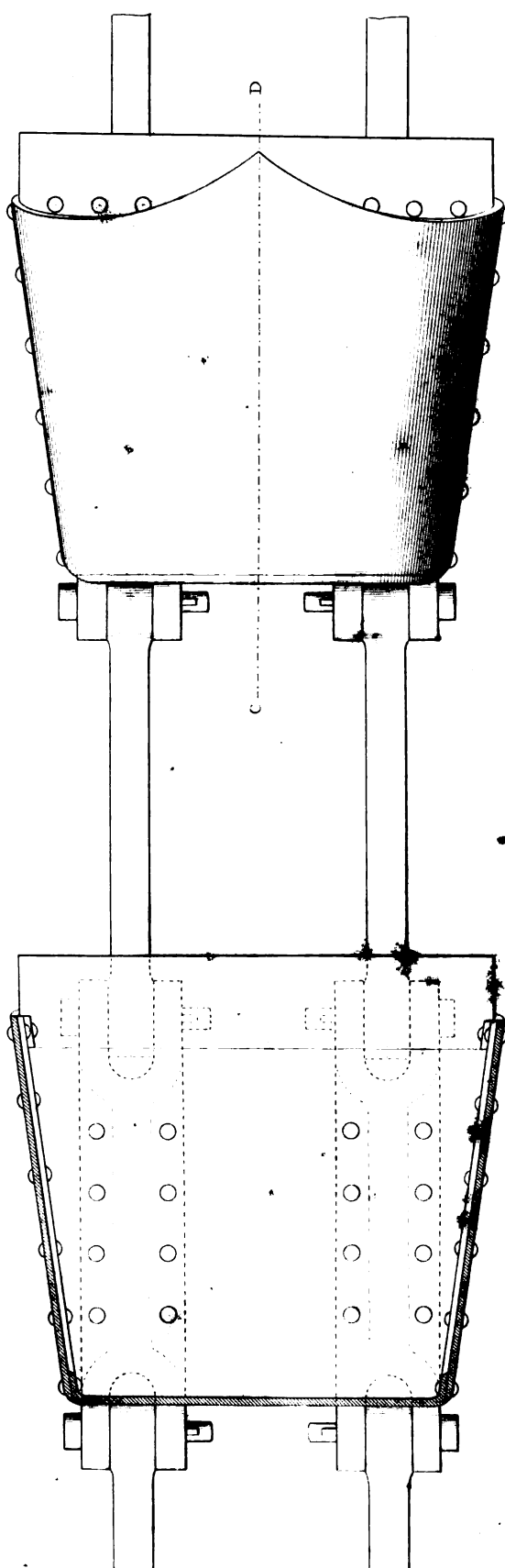
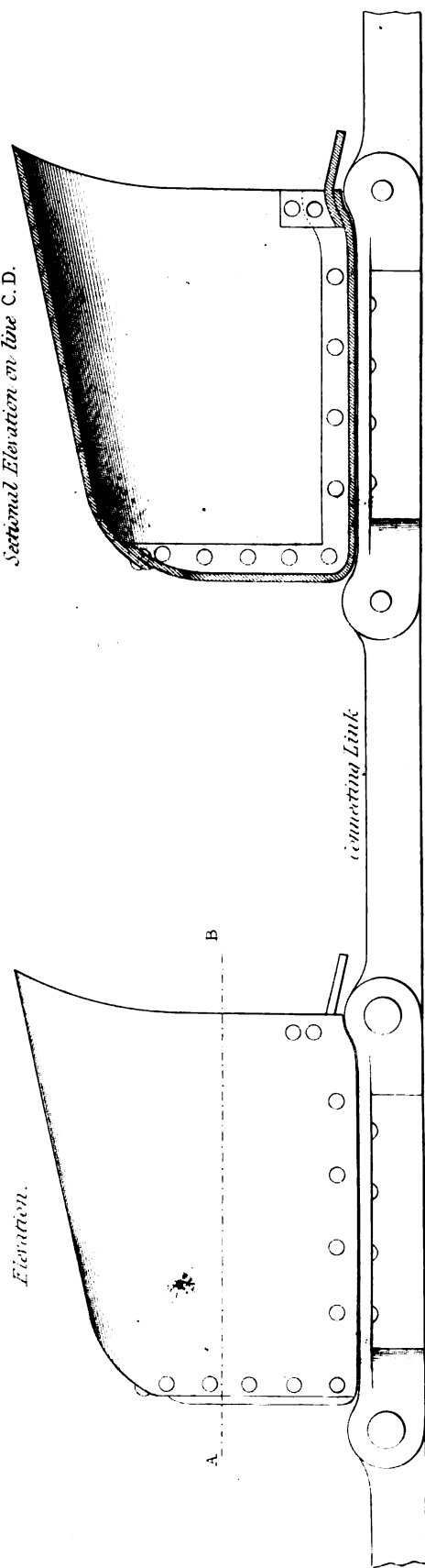
London, Published by John W. & Co. December 1848.

ii Descriptive of the

London, Published by John Wiles, December 1898

6. Dimpsey's edition.

BUCKETS.



inches 1 2 3 feet

London, Published by John W. & Co. Decembris

G. Dempsey & Co.

ON THE ADVANTAGES
OF EMPLOYING
A FRAME-WORK OF MALLEABLE IRON
IN THE CONSTRUCTION OF
JETTIES AND BREAKWATERS,
ETC., ETC.

BY JAMES VETCH, CAPT. ROYAL ENGINEERS, F.R.S.

BEFORE entering upon the merits and details of the project about to be submitted for the construction of piers and breakwaters, &c., it seems necessary to inquire briefly into the nature and action of the waves of the sea, which these structures are intended to withstand and subject, in order that we may arrive at some safe conclusions on the modes of construction best suited to accomplish the objects in view; and also, to avoid any prejudice which may have grown up by admitting existing practices as systems, without due investigation into their fitness.

It is a common and natural error for those who look at a wave, to conceive that the body of water of which it is composed, proceeds with great velocity in a horizontal direction, and is likely to act with a great force upon any body opposed to that presumed motion, and the deception is so complete that, after the oscillatory theory of the wave is understood, it is difficult to disabuse the mind of its early impressions. It must, however, be borne in mind that in deep water while the undulation proceeds rapidly in a horizontal direction, the motion of the body of water in the undulation is comparatively slow, and is almost entirely of a vibratory nature; and such waves, therefore, act much less powerfully on surfaces exposed to their line of action than might have been expected.

In *deep water* the undulations do not extend to the bottom or beyond a limited depth, but where a shelving shore presents itself to an ocean wave, as soon as the

lower surface of the undulating stratum impinges on the inclined plane, it meets a greater resistance in its downward motion, and is reflected more forcibly upwards, and the oscillatory motion of the body of the wave is partially deflected into a progressive one in the direction of the undulation, and as the water ascends the inclined plane, the wave obtains an accumulating impetus, the water is heaped on the shore against the action of gravity, and the progressive motion increases in intensity, until the wave is projected on the shore in an overfall of broken water.

Lieutenant-Colonel H. Jones, of the Royal Engineers, who has paid great attention to the subject of sea-walls of various slopes, and with much industry and zeal has collected a great mass of facts as to the action of waves on them, and on the displacements of the original structure of breakwaters composed of loose stones, has arrived at the practical conclusion, that long slopes towards the sea are the most susceptible of destruction, while those approaching the perpendicular are the least so; and in this manner has shewn from practical experience the truth of the theory. (See Proceedings of the Institution of Civil Engineers for 1842, p. 124.)

The case of the Plymouth breakwater, and others constructed on the same principle, present long slopes or inclined planes to the undulation of the sea, and the effects are consequently the same as those produced by a shelving shore—the vertical oscillations are resisted and deflected by the inclined plane, and nearly the whole vibrating force is converted into a direct battery on the surface of the breakwater, which receives and overcomes the momentum by a dead resistance, as far as its strength will permit.

If on the other hand a perpendicular, or highly inclined surface, is presented to the undulation of the sea, the vertical motion of the water receives no check, it ascends and descends along the face of such a plane without meeting any solid resistance, and the ascent is checked by the increased gravitation of the uplifted body of water, which overcomes its upward force, and causes it to descend again in endless and harmless oscillations.

The erection of the Plymouth breakwater commenced in 1812, and in 28 years 1346 yards in length were completed. This slow progress must be mainly attributed to the interruptions and dilapidations occasioned by storms. On the 9th of January, 1817, the work having assumed a forward state, was assailed by a storm, when 200 yards in length, and 30 in width, of the upper strata, were displaced by the violence of the sea, and the whole of the huge mass was carried over, and deposited on the inner slope of the work.

On the 22nd November, 1824, another storm occurred, and overthrew 748 yards in length, above the low-water mark, being more than one half of the distance *con-*

sidered finished ; the whole surface on the above length to low-water mark, was torn up, and blocks of stone, varying from three to ten tons weight, were displaced from beds where they had been inserted by the utmost labour of man ; but so tremendous was the force exerted by the sea, that the blocks on the outward slope were carried over the breakwater, a distance of 138 feet, and piled up on the inner or land side, and nearly 200,000 tons of stone were removed on that occasion.

If the Plymouth breakwater had been intended to demonstrate the amount of destructive force which could be attained by resolving the undulations of the sea into a progressive motion, then the end would have been fully attained ; but as a work of art to shelter shipping, it may *now* be permitted to hazard an opinion, that the form and structure of that work are conditions or examples rather to be avoided than followed in any future erection having the same object in view.

The Plymouth breakwater is essentially composed of large blocks of compact limestone ; but these have been eaten into and honeycombed by the ravages of the *Saxicava Rugosa*, and the stones have been reduced in weight and strength, and will continue to be so from the same cause, and also by attrition ; and thus the capability of resistance goes on diminishing, and unless constant repairs and additions are being made, that immense pile of loose stones may be scattered on a wide surface, or reduced to a number of banks and shoals dangerous to navigation. The expense of this breakwater may be roundly stated at £1000 per lineal yard^a.

On the 30th May, 1840, the Commissioners appointed to survey the Harbours on the South-eastern Coast of England reported on the subject of harbours of refuge, and recommended the construction of one of these near Margate, another near Dover, and a third near Beachy Head. The gentlemen comprising the Commission are justly eminent in their professions, and we may rely on the choice of the position and the linear form of the proposed harbours being judicious and creditable to their talents and judgment. It must, however, be observed with regret, that the Commissioners recommend the section and structure of the sea-walls or piers should be on the same principle as that in Plymouth Sound, as a detached breakwater, or connected with the shore by stone piers similar to those of Kingstown Harbour, near Dublin.

The Commissioners farther recommend that the sea-walls or piers be formed of large blocks of the hardest chalk, and cased with granite or hard limestone ; and they estimate the cost of the three harbours at £2,000,000 each, which will be found to amount to about £660 per lineal yard.

^a The author of this article is chiefly indebted for his statements respecting the Plymouth breakwater, to Mr. J. Claringbull's *Concise History and Progress of that work* (1840).

It will probably be admitted that such a form and structure of sea-wall on the south-east coast of England, while it would be liable to the same objection as that noticed above, in regard to the breakwater in Plymouth Sound, would have the farther disadvantage, that the blocks of chalk being much more frangible than those of Plymouth limestone, they would run the chance of being demolished in the progress of erection, while they are equally subject to be honeycombed by mollusca; and if, through means of any storm, such piers should be overthrown, it is much to be feared the fragments and debris would form into banks likely to prove still more dangerous to navigation than what would arise from the destruction of the breakwater in Plymouth Sound. It ought not, however, to excite any surprise that the Commissioners recommended the adoption of such a form and structure of section, as, under any *existing practice*, the mode selected, however objectionable, must have appeared the most available one to apply to the case of the proposed harbours of refuge.

The insufficiency of any of the existing modes to effect the objects required, in a satisfactory and economical manner, induced the author of this article, about three years ago, to study the subject, and to devise some means of executing the work which would be free from the objections noticed, and the employment of upright rods of wrought iron presented itself to him as a safe and practicable contrivance for effecting the objects, viz., forming structures nearly perpendicular in deep water in exposed situations, and on irregular and bad foundations; or, in fact, where the construction of upright pieces of masonry was impracticable, or excessively slow and costly in their erection.

With the above preliminary observations, it is now proper to proceed to the description of the project for employing a frame-work of malleable iron in the construction of jetties, breakwaters and embankments, &c.

The great features of the project are those of ease and celerity of construction, moderate cost, and freedom from risks in the execution.

It is presumed that the mode of construction here proposed may be employed in situations where exposure to storms would permit no other to be attempted; also in situations where the usual mode would prove too slow, or too costly of execution, from the nature of the foundation.

The mode of construction upon this project consists essentially in the application of upright rods of malleable iron, steadied and fixed in their places by passing them through apertures in two parallel and horizontal frames of flat iron, provided with corresponding orifices to receive them; the lower frames being placed about three feet above the low-water mark, and the upper frame about three feet above the high-

water mark, or at such other convenient distances apart as the circumstances of the case may demand.

The horizontal frames may be conveniently constructed in short lengths, say of four feet each, and an additional piece of frame may be connected with the preceding one by round bolts passing through loops, forming so many moveable joints, that the frames may be the more easily raised, lowered, or adjusted to the required level, if from the settlement of the upright rods they have swerved from their original horizontal position.

The new lengths of frames having been bolted to the preceding ones, and retained in a horizontal position by diagonal stays, are ready to receive the upright rods, which are then to be dropped separately through the corresponding apertures of the frames, and each allowed to take its bearing separately by its own gravity, or by such farther pressure as may be deemed proper. When the rods have taken their bearing and settlement, a row of sloping rods have to be added to each side of the jetty, inclining inwards one foot in ten or twelve, to give lateral support; and at this stage of the operation, it is proposed to key on to the rods the iron collars for the permanent support of the horizontal frames and the platform.

It will be seen from the above description with what celerity the work might proceed, supposing the materials to be all ready; and if we suppose the bottom of the sea to be a compact material, such as chalk, but with a very uneven surface, we also perceive how readily on this plan the jetty would obtain a firm and equal bearing on its foundation, and that the same result would follow if the uneven surface of chalk was covered by an even or uneven deposit of soft sand or mud to a moderate depth, circumstances which would prove serious obstacles to the construction of piers of stone or timber, particularly if on an exposed coast, as that for instance of the Isle of Thanet.

In the construction of a pier or jetty on the principles of this project, many details or particulars would have to be governed by the circumstances of tides, foundation, exposure, &c. For the sake of illustration, however, we may suppose such a coast as that last mentioned, and that it is required to extend a jetty a thousand yards from the shore.

It might be advisable to commence by carrying out a stone pier to where a solid foundation could be had at low-water mark, but not farther, and from thence to employ the iron rods to the required distance. The configuration of the lines of iron rods may be varied in respect to the kind of work required, but in this instance, and in most cases of jetties and breakwaters, it is proposed to use double lines of upright rods about a foot apart, and with the same interval between the individual rods.

Again it is proposed to place the double rows from three to six feet apart, and intersecting each other at right angles, one double row being parallel to the line of the pier, and the other perpendicular to it. This principle is adopted, as it presents many facilities for the ulterior operations. (See the Plan and Section.)

The superstructure or platform may be completed by laying half balks longitudinally over the upper horizontal frame of flat iron and planking across the same, leaving intervals of two inches between the planks for the escape of any wave that might press upwards on the platform.

When a jetty has been constructed in the foregoing manner, it affords the means of giving any resistance to the waves, which may be deemed requisite. It is presumed that a *ground swell*, crossing the line of the jetty, upon which it could exert little force, would nevertheless be cut into so many sections, and so dispersed in its action, as to have its force or momentum much reduced; but from the number of cells or intervals formed by the upright rods, any requisite number of them may be filled with soft yielding substances, such as sea-weed, &c., or with more solid materials, such as concrete, timber, or stone; though by simply filling the centre longitudinal row of cells with a particular kind of sea-weed, which is known to keep sound after twenty years' use, the undulation might be completely stopped.

In the same manner in which a jetty from the shore is constructed, a sand-bank may have a breakwater erected upon it. One islet may in like manner be joined to another, or to the main land, to form a shelter for shipping; and all these operations may be performed at moderate cost, and with great expedition; and finally, if the structure is only wanted for a temporary purpose, the iron rods can be withdrawn and used elsewhere.

The size of the iron rods may be various, and round, square, or flat; or even hollow tubes may be used, according to the circumstances of each particular case. The advantages of iron rods over wood piles, for the purposes mentioned, are various. Wood is subject to the ravages of the teredo; it is bulky, and difficult to handle; the piles must be driven with machinery, while the floatage and resistance of the timber to the surge in exposed situations, entail great comparative difficulties. On rocky ground there can be no holding to the timber; on the other hand, iron rods are small in bulk, and any length by additions may be procured; iron is easier handled, and from its weight and slender form would readily sink to the required depth, without the aid of machinery, and when fixed in its place would offer little *dead* resistance to the undulations of the water.

In some cases, as in a hard superstratum, it might be necessary to steady the rods by dropping concrete between the compartments of the jetty; and if the rods, after

passing through the holes of the lower frame, were fixed together at their base by fours, or by whole rows, with iron rods, the stratum of concrete would hold all down with great effect, and a bed of three or four feet thick would probably be sufficient in most cases.

Again, if it became necessary to follow this construction on ground which was soft to an immoderate depth, a bed of loose stones might be first formed by discharging them from the end of the finished portion of the jetty, and the rods, after passing through the lower frame, might be firmly inserted into small blocks of stone, previous to being lowered to the bottom, and the rods would thus be supported on the artificial bed. In deep water, it is proposed to unite the rods by fours by cross bars at every fifteen feet, to give them a sufficient stiffness.

These different cases have been mentioned to shew the general application of the principle, but it is conceived the superiority of the plan will be chiefly found in exposed situations, in deep water where there is a considerable deposit of sand or mud on a firm substratum.

The iron frame-work just described with its stage or platform is the first and most important step in the construction, and may, with a little addition of iron, complete the defence against the waves by procuring still water, since a single row of perpendicular bars placed close together, or nearly so, would produce the effect required.

No doubt objections may be made to breakwaters composed entirely of iron, from the decay which might be attributed to the material; but besides the objection being an exaggerated one, there is good reason to hope that means can be found to prevent the corrosion of the iron.

Considering, in the next place, the iron frame as a first step to a more solid structure, it is proposed to fill the interior space with concrete; this arrangement would give the two substances a mutual protection, for it is important to bear in mind that any oxides which the iron might form would enter into new combinations with the concrete, and act as a powerful cement; as has been often observed to take place under similar circumstances.

The modes of filling the frame-work with concrete may be various. A portion of the frame-work may be inclosed in a temporary manner from the agitation of the sea, by lowering casings of wood or iron, and by removing these to another portion when the first was secured. Within these casings the concrete would be lowered in boxes, and discharged by moveable bottoms, so as to avoid any diffusion amongst the water in the course of its descent, or transverse spaces may be inclosed by filling the inter-

vals and ends with sea-weed or brushwood ; and when these inclosed spaces became filled and consolidated, the packing would be withdrawn, and the intervals treated in the same manner ; and in these different modes the operations may proceed upwards in different stages, stratum super stratum, to give good joints for settlement and repose.

The concrete may also be formed and allowed to harden in iron cradles, above the surface of the water, and be lowered in that state to the bottom with facility and accuracy, so admirably suited is the iron frame-work for facilitating all such operations.

It is not necessary here to notice *all* the details that might be necessary in conducting the process, but it may be mentioned, that as soon as portions of the iron frame-work and platform are completed, it is proposed to lay down on the last, two tramways for the convenience of bringing up materials, and for carrying a moveable crane, which would be useful in conveying the iron rods and frames to their destined places.

If the bottom of the sea is soft or oozy, it would be necessary to solidify the same by dropping broken stone until the surface became hard, previous to lowering the concrete.

When the surface of the structure of concrete reached the line of low-water mark, a choice of operations would be offered ; and from that point it is proposed to commence facing the concrete with brickwork set in cement, and to tie the face walls together with cross ones, filling the intervals with the ordinary concrete.

It is, however, to be observed, that without waiting for the ulterior steps of construction, that the iron frame may be used to give the protection of a breakwater, by filling some of the cells with sea-weed and brushwood, leaving the works of consolidation to follow, (if found necessary,) as convenience dictated. It will now be proper to offer a rough estimate of the cost of an iron frame jetty, made solid with concrete, &c.

The iron rods are supposed to be two inches in diameter, and to penetrate the ground six feet, to be six feet above high-water mark, and to have a length of thirty-six feet between high-water mark and the ground ; presenting a total height of forty-eight feet, which, it is presumed, will be an average of what would be required in harbours of refuge ; (width of piers twenty-four feet.)

Estimate per lineal yard.

11 $\frac{3}{4}$ tons of iron, at £5	£58	15	0
50 cubic feet of timber, at 2s.	5	0	0
Workmanship on materials (fitting)	6	14	0
Ditto ditto (fixing)	3	7	0
86 cubic yards of concrete, at 7s.	30	2	0
10 cubic yards of brickwork set in cement, at £2	20	0	0
Sundry small items not enumerated	12	7	10
Contingencies by accidents and unforeseen difficulties	12	7	10
	<hr/> £148 13 8 <hr/>		

It has been shewn that the Plymouth breakwater cost about £1000 per lineal yard, and that the estimate of the harbours of refuge on the coast of Kent amounts to about £660 per lineal yard, but when we consider the immense contingencies to which the latter would be liable, we may doubt if they would not be found to prove equally costly; for though the destructive force of the sea may be greater in Plymouth Sound than at Dover, the materials are better at Plymouth Sound, and more accessible to lighters than the lower chalk could be for Dover; in fact, Plymouth Sound possesses every advantage for yielding a good material, and loading it, which the North Foreland, Dover, and Beachy Head, do not. Looking, however, to the actual cost at one place, and to the estimated cost at the other, it may be safely assumed, that the cost of the iron frame jetty will only be one-fifth part of the amount of such structures.

The Plymouth breakwater took twenty-eight years to complete, and it is understood, fourteen years has been estimated as the required time for the harbour of refuge at Dover; now, in the construction by iron framing, it is reasonable to assume that a frame of four feet may be set each tide, and by working from two ends, sixteen feet per diem ought to be performed in good weather; the length of sea face of the proposed harbours of refuge average 9100 feet, so that 569 days would be required to complete the iron framing for one, and allowing for Sundays and bad weather, the work would be accomplished in less than three years, say in one-fifth of the time estimated for the Dover harbour, on the principle of construction of the breakwater in Plymouth Sound.

In carrying out an iron frame-work to inclose a space for a harbour of refuge, the operations would conveniently commence from the two extremities of the basin bounded by the shore, and proceed uninterruptedly to the opening for shipping.

nearest to the centre of the sea line, neglecting all intermediate mouths or openings, in the first instance, for the convenience of bringing up the materials to the most distant points, and at a subsequent period withdrawing the iron frames where lateral openings are intended.

As a skeleton pier, the iron frame-work may have any degree of stability given to it by superadding to the series of upright rods other series of sloping ones, inclined against each other, and calculated to resist any thrust or force in a horizontal direction.

The frame-work may be anchored, if thought necessary, by means of screw piles, or by blocks of stone or concrete, to which the platform would be tied down by connecting rods, tightened by screw purchases.

The stability of the iron frame-work may be increased on reaching deep water, either by giving a greater breadth of pier or by adding a sufficient number of buttresses of the same frame-work, or by others of a more solid material, for the insertion of which the previous framing would offer many facilities.

The iron frame-work being completed, as the skeleton piers of a harbour of refuge, it would be desirable to test its powers in the first place without any farther addition, and then to proceed to fill so many of the cells with sea-weed, as might be found sufficient to stop the undulations of the sea.

The great objection to solid works for inclosing harbours has been the tendency to deposit silt, sand, and shingle inside the basin, and to render it eventually too shallow in some places for the purposes intended, but in respect to a solid structure formed upon an iron frame-work, such an objection might in a great measure be provided for, since, by filling the cells with sea-weed for a few years, it would be observed where a tendency to deposition took place, and so much of the frame might then be left open, (where necessary,) to admit currents to sweep away the depository matter.

It may be safely assumed, that in many places where it was determined to construct jetties of solid masonry, a frame-work of iron, properly modified, would prove a convenient and useful preliminary measure to carry out in advance of the more solid structure, for the purpose of bringing up and lowering the stones, and facilitating and expediting the operation, the iron rods being withdrawn to admit the masonry as it advanced. The stones might thus be lowered with so much accuracy, as to render recourse to the diving bell not only less frequent, but also more safe and available in all weathers.

When it might be proposed to carry out a solid pier formed by concrete on an iron frame-work to a great distance, much additional strength would be obtained by

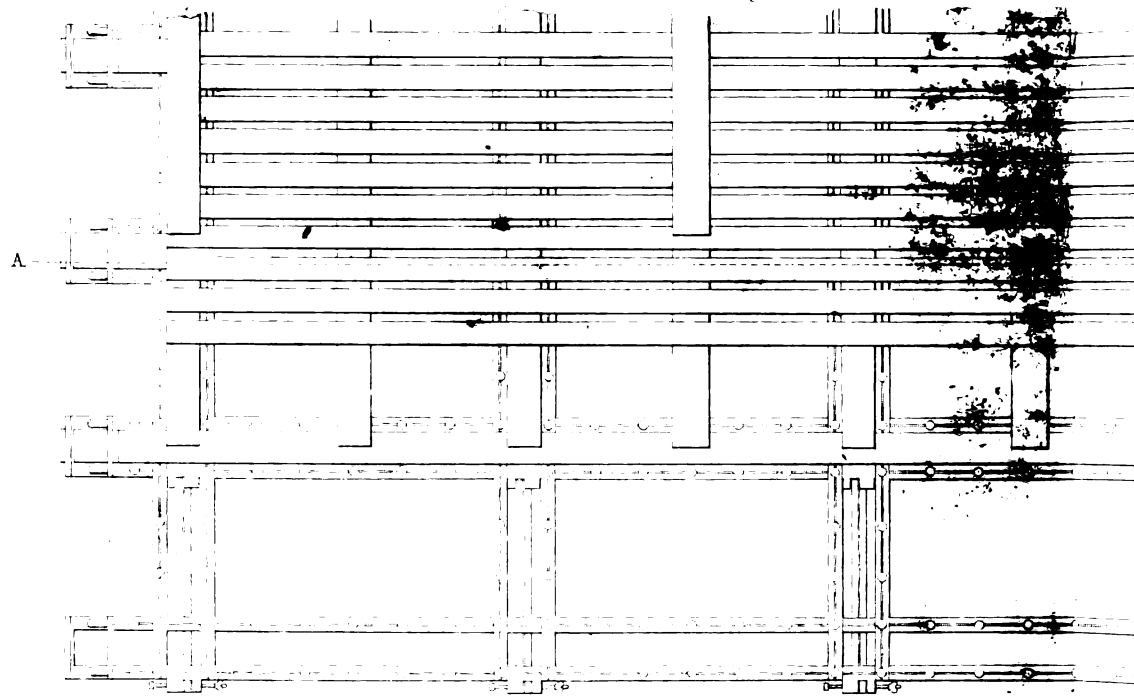
carrying out two *narrow* parallel iron frames, (instead of one wide one,) and when the concrete in the two frames was consolidated, filling and backing up the interval between them with chalk, or such other good material as the vicinity afforded ; the same being brought up and deposited in the manner usual on a railway embankment, which would be effected at little expense ; lastly, the whole breadth of pier to be bound together at every fifty yards, by cross frames of iron, made solid with concrete.

In the foregoing description, the writer has shewn the mode of operation under his principle of construction for carrying out a pier from the shore, and he proposes, in a future communication, to describe in what manner the same principle may be applied to erect breakwaters on sandbanks, which are either constantly submerged or during high water, and he also proposes to show the application of the same principle to the construction of embankments and bridges.

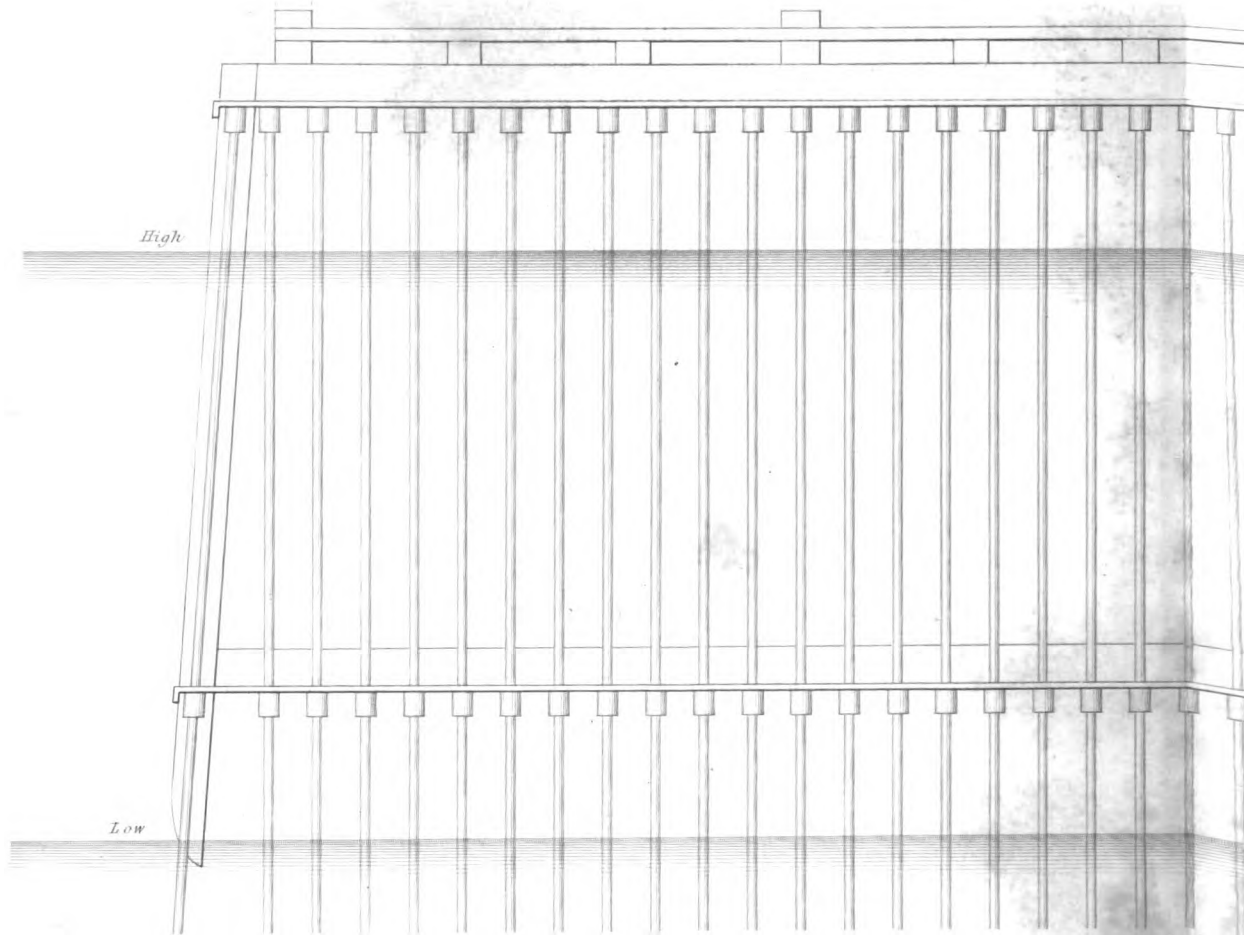
In devising a method of constructing breakwaters, &c., which should possess some new advantages, and be free from some old objections, the author of this article had not in view the particular benefit of the iron trade. But if his project should be so fortunate as to include so desirable an object, that circumstance will form no small recommendation, at a time when a large portion of our working population, engaged in the manufacture of iron, have been thrown out of employment, and when all connected with it are suffering more or less from its depressed condition.

One of the harbours of refuge proposed for the south-east coast of England, if constructed of iron frame-work, would employ 36,000 tons, and if the principle were extended to sea-walling and embankments and the piers of bridges, for all of which (in many cases) it would be usefully available, the annual demand for iron would be materially increased, particularly if such uses were extended to the colonies and foreign countries.

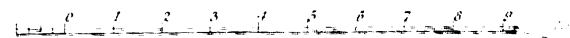
Plan of Jetty

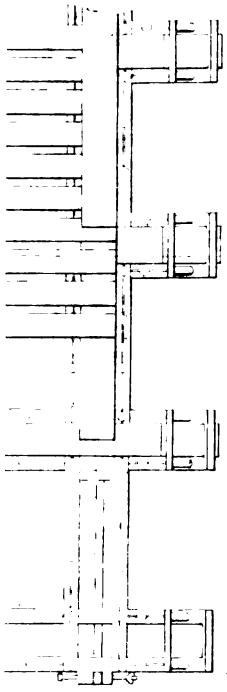


Section on line A.B.



London Published by John Wale, December 1843.

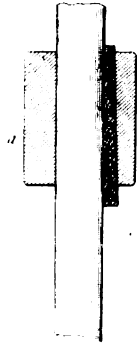




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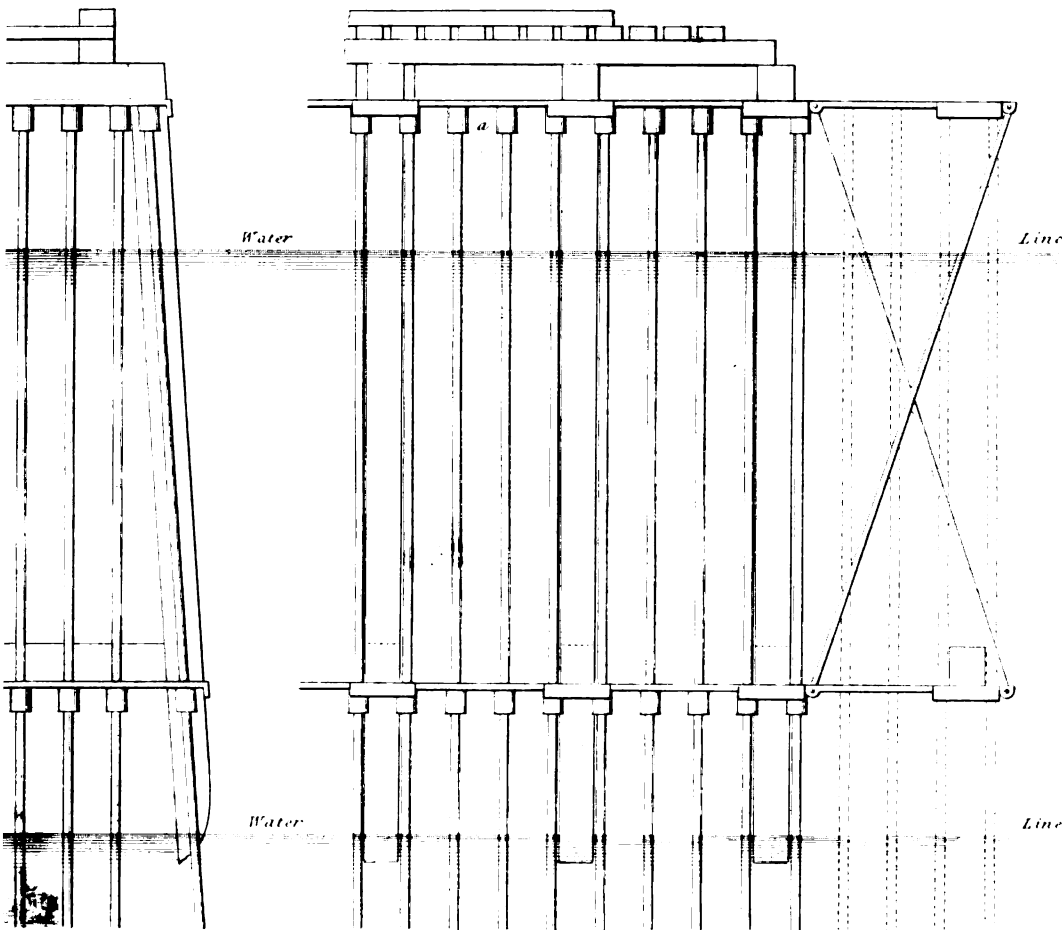


a



a

Elevation shewing the mode of construction.



Water

Line

Water

Line

B

B

20 feet.

J.W. Lawrence

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PART II.—ENG. VI.

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in the hope that in future, before the expiration of each succeeding year, the volume of previous proceedings will be issued.

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| Reports on Mechanics, &c., Fine Arts, Statistics, Natural History, Naval Architecture, Schools. | A plan for converting Parallel into Rotatory Motion, by Mr. Alfred Martin. |
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